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THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME V.—SERIES II. New
[2] (= 11-13)

DUBLIN:

PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

WILLIAMS AND NORGATE,

14, HENRIETTA STREET, COVENT GARDEN, LONDON;

20, SOUTH FREDERICK STREET, EDINBURGH; AND 7, BROAD STREET, OXFORD.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK.

1893–1896.

Wb/51/625
25H

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[SEPTEMBER, 1895.]

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME V. (SERIES II.)

[1,2] (=11–13)

XI.

THE COURSE AND NATURE OF FERMENTATIVE CHANGES IN NATURAL AND POLLUTED WATERS, AND IN ARTIFICIAL SOLUTIONS, AS INDICATED BY THE COMPOSITION OF THE DISSOLVED GASES.

(PARTS I., II., AND III.) BY W. E. ADENEY, Assoc. R.C.Sc.I., F.I.C., Curator and Ex-Examiner in Chemistry in the Royal University, Ireland.

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1895.

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[Read April 24, 1895.]

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Introduction.

IT is, I believe, now generally accepted that the organic matters which, by one means or another, find their way into surface waters, are oxidised, and eventually reduced to simple substances by the operations of micro-organisms, and not by mere chemical changes independent of them. To these operations the term "fermentation" is usually applied.

This explanation rests chiefly on the results of bacteriological research, and especially upon the fact that the germs of these micro-organisms are present, practically, everywhere—in the air, in water, and in ordinary soil; and that they require but the necessary pabulum, such as refuse animal or vegetable matters, in a neutral or slightly alkaline medium, for rapid growth and multiplication.

The importance, from the chemists' point of view, of the recognition of the true agencies at work in setting up processes of oxidation in natural and polluted waters does not appear to have been sufficiently realized.

It suggests at once the possibility of classifying the organic matters to be met with in natural and polluted waters into two classes, viz. fermentable and non-fermentable, and of differentiating the one from the other when present in the same water.*

We know that some of the organic matters found in natural waters either do not ferment at all, or do so with difficulty, such as peaty colouring matters and the organic matters found in good well and spring waters. Of a like character, also, are those which are found in sewage-water after they have undergone complete fermentation under aërobic conditions, such as obtain during slow filtration through sand or soil.

Amongst the fermentable matters may probably be included most, if not all, known organic substances, with the exception of antiseptics. Dr. Munro has shown, in his interesting and suggestive Paper on "The Formation and Destruction of Nitrates and Nitrites in Artificial Solutions and in River and Well Waters,"† that not only are such simple bodies as acetates and oxalates attacked by the organisms usually present in soil and water, but also such unlikely substances as ethylamine, cyanides, and thiocyanates, and he concludes that it would be difficult to make out a list of known organic compounds which are not fermentable under these conditions.

One of the most obvious results of the fermentation of small quantities of an organic substance in fully aërated water would, no doubt, be an absorption of the dissolved atmospheric oxygen therein, and an evolution of carbon dioxide; and if the water were preserved during fermentation under conditions, such that gases could neither escape from, nor gain access to it, these results would also be the most easily detected by chemical means.

A few tentative experiments carried out on the lines here suggested showed very distinctly that the above view was correct, and that even relatively minute

* It is due to Dr. Dupré to make reference in connection with this point to a short Paper by him, entitled—"On Changes in Aëration of Water, as indicating the Nature of the Impurities present in it," and published in the Report of the Medical Officer to the Local Government Board, 1884.

† "Chem. Soc. Journ.," vol. 49, p. 677. See also p. 651.

quantities of fermentable matters, such as fresh sewage, when mixed with good river water, soon indicated their presence by causing an absorption of dissolved oxygen, and an evolution of carbon dioxide.

These experiments satisfied me that the consumption of oxygen and the formation of carbon dioxide, which must occur during the fermentation of small quantities of organic matters in a water, when taken together, provided a most delicate indication of the presence of such matters in a water.

But little consideration, however, was necessary to lead one to anticipate that a method of inquiry, based upon the determination of the changes in composition of the dissolved gases, would lead to much more definite results, especially when coupled with the determination of the inorganic nitrogenous products of the fermentation—such fermentation to be conducted under suitable conditions.

In explanation of my meaning, I would refer to the more recent researches on nitrification.

Dr. Munro,* Dr. P. F. Frankland,† and Mr. Warrington,‡ have all demonstrated that the fermentation of ammonia to nitrous acid may occur in inorganic solutions to which no organic matters have been added. M. Winogradsky§ has extended these observations, and has not only shown that a nitrous fermentation proceeds when organic matters are rigorously excluded from the cultivating inorganic solutions, but he has also demonstrated that organic matters are formed from inorganic materials at the same time, the first step in their formation, possibly being, as suggested by him, the production of an amide from ammonium carbonate.

We find, moreover, abundant evidence given in Munro's Paper, that unfermented non-nitrogenous organic matter is positively prejudicial to nitrification, and that, if present with ammonium salts in a water containing soil or water organisms, they undergo fermentative changes before nitrification sets in.

We have evidence also from the same author's Paper that the nitrification by soil organisms of *nitrogenous* substances, with no added ammonium compounds, follows a similar course. A putrid bacterial fermentation first takes place, during which nearly the whole of the organic nitrogen is converted into ammonia, and this ammonia apparently only begins to undergo nitrification after the first fermentation of the organic matter originally present has been completed.

If, then, the nitrification, by the mixed organisms which ordinarily occur in soils and natural waters, of organic substances containing nitrogen, or mixtures of these containing no nitrogen with ammonium compounds, takes place in two distinct stages as above indicated, it is probable that accurate determinations of the more obvious products of each stage of fermentation, viz. carbonic

* *Loc. cit.*, p. 653. † "Phil. Trans.," 181, p. 107. ‡ "Chem. Soc. Journ.," 59, p. 484.

§ "Annales de l'Institute Pasteur," vol. iv., pp. 213, 257, 760; vol. v., pp. 92, 577.

dioxide and possibly ammonia in the one; and of carbonic dioxide (if any be formed) and nitrous and nitric acids in the other, together with accurate determinations of the free oxygen consumed during both stages, would afford *data* for estimating the actual quantity of fermentable matters present in polluted water with sufficient accuracy for the purpose of water analysis.

Such a method of examination as here suggested promised results of a most definite character, and of especial value for the examination of polluted drainage waters, in that they would probably afford the means of accurately estimating the quantity of such water which could be safely allowed to drain into a river or stream of a given size, and would thereby lead to the possibility of formulating exact practical standards of impurity for drainage waters, which standards could be graduated according to local conditions of volume and flow of the stream.

The method of examination which I have sketched was, however, open to possible objections, which could only be answered one way or the other by a full experimental investigation. For instance, a water under examination would always contain mixed organisms, and the selective chemical functions of these might vary to such an extent that in no two experiments with the same water would similar values for the products formed, or oxygen consumed, be obtained. It might further be objected that a given result was due to the accidental presence of a particular organism.

There were, however, good reasons for believing that, if precautions were taken to experiment under certain conditions, as regards the relative quantities of fermentable matters, and of dissolved oxygen, the growth of similar sets of organisms, so far as chemical functions are concerned, would be encouraged, and that the products obtained thereby would be very similar in chemical characters.

The actual quantity of carbon dioxide, and no doubt of nitric acid, but probably to a more limited extent, formed relatively to the quantity of oxygen consumed during fermentation of similar volumes of different polluted waters, would no doubt vary with the composition of the organic matters originally present in them. But, for the purpose of water analysis, this would not affect the value of the quantity of oxygen consumed, as a quantitative index of the amount of the fermentable matters originally present, since this quantity would probably exactly represent that which a similar volume of the same water would require when discharged into a natural watercourse.

It must be remembered, too, that, by the complete fermentation under aërobic conditions of organic matters in an ordinary water, much the greater proportion of the organic carbon and organic and ammoniacal nitrogen undergo complete oxidation to carbon dioxide and nitric acid respectively, and only a very small proportion of either of these constituents remains fixed as fermented organic matters, and that variation in fermentative products due to selective chemical

action of the mixed organisms present would probably be shown most prominently in the last-mentioned products, viz. the fermented organic matters.

With these considerations in mind, I commenced a series of experiments as long back as the autumn of 1891. The slowness, however, of some of the fermentative processes under observation, combined with long-continued interruptions in the course of the work by other duties, has hitherto prevented my being in a position to publish any results. The scope of the investigation has also widened, and very many points have arisen and demanded experimental study, which were not anticipated at the commencement of the work. Even now, I cannot claim to have finished the investigation of many of these points.

My experiments, however, in so far as the original object of the investigation is concerned, have now reached a sufficiently advanced stage, I think, to render any further delay in publication undesirable. I therefore propose, in this communication, to deal with such experiments as bear directly on the question with which I started this investigation, viz. *whether the amount of the dissolved oxygen consumed during the complete fermentation of a polluted water might not be regarded, for the purpose of water analysis, as a quantitative index to the amount of fermentable substances originally present in it, provided that during the process care is taken to have the oxygen in excess in the water.* And, further, whether it might not be possible to separately estimate the volume of dissolved oxygen consumed during each of the two distinct stages in which it is supposed the nitrification of organic matter takes place. I say supposed advisedly, because it cannot be regarded as having been experimentally proved that the nitrification of nitrogenous organic substances, or of non-nitrogenous organic substances mixed with ammonium compounds, really takes place in two stages, except when the fermentation is carried on under partially aërobic and partially anaërobic conditions. There can be little doubt, for example, that in Munro's * experiment on the nitrification of gelatin, in which, during the earlier stages of fermentation he noticed putrefactive products and the formation of ammonia, free oxygen must have been entirely absent from the lower layers of the solution he employed, judging from its strength.

It cannot be taken for granted, therefore, that the oxidation by fermentation of gelatin, or other nitrogenous substance, in the continued presence of an excess of free oxygen, would be "progressive," as above described, rather than "complete from the commencement."†

I may, however, anticipate in this particular, the experiments which I have to describe, and state that they all go to show that the fermentation of such bodies by the mixed organisms of soils and waters takes place in two perfectly distinct

* *Loc. cit.*, p. 641.

† See Schützenberger on "Fermentation," p. 244. International Scientific Series, 1891.

stages, even in the continued presence of free oxygen, and that in the first stage the organic substance is simply broken down, the carbon and nitrogen, if present, being converted largely into carbon dioxide and ammonia, a small quantity of organic matter, however, remaining as such, but in an altered form; that in the second stage the ammonia is oxidized to nitrous or nitric acids, or both, and that, at the same time, the organic matters resulting from the first stage may be partially or completely oxidized, carbon dioxide and possibly nitric acid being formed;—also that the second stage does not commence until the completion of the first. I shall call these two "first" and "second" stages of fermentation for want of better terms; new terms are, in fact, wanted to describe them properly. My friend Dr. E. A. Letts has suggested to me a term which seems to be very suitable for the first, viz. bacteriolysis.

Method of Experimenting.

In considering this question, three conditions which the method adopted would be required to fulfil had to be borne in mind:—

1. It should not be possible for any gas, during an experiment, to gain access to, or egress from, the vessel in which the experiment was to be carried on.

2. It should be possible to easily and accurately regulate the quantities of dissolved oxygen and of fermentable matters, relatively to one another in a liquid to be examined, so that the former should be in excess of the latter, or *vice versa*, just as required.

3. The external conditions of a liquid during fermentation should be similar in all respects, and such as to ensure, as far as practically possible, that every part of the liquid throughout its mass should be chemically similar at any interval of time during the continuation of the experiment.*

These necessary conditions made it impossible for me to use the method of liquid cultivations, as commonly employed by bacteriologists, viz. nutrient liquid media, in which the relative quantities of fermentable matters and dissolved oxygen are not specially regulated, and which are kept in bottles or in flasks, which they only partially fill.

With such a method it would be quite possible, as bacteriologists have generally observed, to have a fermentation in the continued presence of an excess of atmo-

* In connection with this point, see Dr. P. F. Frankland and Mr. Frew's very interesting experiments, described in their Paper on "A Pure Fermentation of Mannitol and Dulcitol."—C. S. J., 61, p. 254.

spheric oxygen proceeding in the portions of the liquid immediately adjoining the surface exposed to the air in the vessel in which it was kept, and at the same time a fermentation in the practically complete absence of dissolved oxygen in the lower portions of the liquid. The only possible way of ensuring the third condition above stated, was to keep the water or liquid under observation in bottles completely filled and carefully closed with glass stoppers. The difficulties to be anticipated in practically carrying this out were those which would certainly arise with unavoidable alterations of the temperature of the liquid during the continuance of the experiment. With fall of temperature, there would be a tendency to draw air into the bottle, and with a rise there would be a tendency to expel a portion of the liquid from it, while with both rise and fall of temperature, there might be a disengagement, and possibly, in consequence, a loss of dissolved gases.

I found, however, that by keeping the bottles immersed, neck downwards, in distilled water, in large glass vessels which were covered with glass plates, and by exposing them to a temperature as equable as possible, that these difficulties could be overcome to such an extent that they could not give rise to errors sufficiently large to materially affect the results.

I shall again refer to this subject when dealing generally with the probable errors of the experimental results.

The foregoing consideration of the third necessary condition to be established in my method of experimenting has, it will be observed, included the first. There remains now for discussion the second condition.

For the purpose of this Paper it was of chief importance to observe the products of fermentation which had been carried on in the continued presence of an excess of oxygen relatively to the quantity of matter to be fermented.

It was also of importance to determine whether the complete fermentation, on the one hand, of the nitrogenous organic matters, and, on the other hand, of non-nitrogenous organic matters mixed with ammonium compounds, into carbon dioxide, water, and nitrous or nitric acids, in the continued presence of an excess of oxygen, was complete from the commencement or was progressive.

To effect these purposes, I adopted the general plan of commencing with strong solutions of sewage-waters, or of fresh peat, or of organic and inorganic substances of known strength and composition, in which the quantities of fermentable matters were in decided excess, relatively, to the quantity of dissolved atmospheric oxygen present, and then of making a series of gradually increasing dilutions with good tap-water, or, when necessary, with distilled water, such that the conditions should gradually become reversed, the dissolved oxygen in the higher dilutions becoming predominant in quantity. By this means I hoped to obtain results which would quantitatively indicate the changes resulting from the

fermentation of various fermentable matters under gradually varying condition from that in which the fermentable matters were in excess to that in which the dissolved oxygen was in excess.

One further general condition which had to be attended to in all the experiments need scarcely be mentioned: it was to make provision for keeping the liquids under observation in a slightly alkaline condition during fermentation. This was invariably done by adding, when necessary, very small quantities of pure dry sodium carbonate, which consisted partly of the normal carbonate and partly of the bicarbonate. When experimenting with sewage-water, it was found to be quite unnecessary to add any of this or other mineral substances. All the solutions were kept in the dark during fermentation.

Apparatus Employed.

The bottles I have employed for preserving the waters or solutions under experiment, out of contact with air, have been made in two forms: one, the ordinary bottle-form with short necks; the other of flask form, with long, somewhat narrow necks. Both forms have been made of stout glass with very carefully ground stoppers. The capacity of the bottles has varied, according to circumstances, from about 300 c.cs. to 2500 c.cs.

As before stated, the bottles, when filled, were carefully stoppered so as to leave not a trace of air bubble in them. To avoid the possibility of small quantities of air passing into them between the neck and the stopper, they have been kept neck downwards immersed in distilled water. Under these circumstances, a little distilled water might be drawn into the bottles, or a little solution expelled from them, but not in sufficient quantity to introduce material error, provided the temperature of their contents was not allowed to vary much. When, from any cause, such as considerable variation of temperature, or the formation of gaseous products, other than carbon dioxide, during fermentation, disengagement of gas during the course of an experiment was to be anticipated, such gas would remain in the bottle, since this latter was kept neck downwards, and some liquid would be expelled from it between the neck and the stopper. It would be necessary, of course, to collect this gas, and separately measure and analyse it. To meet this special case, the flask-shaped bottles, with long narrow necks mentioned above, were employed. The neck of each bottle was graduated from the bottom of the stopper downwards, as follows: the bottle was completely filled with water, and the stopper firmly inserted; the stopper was then carefully taken out, and the height of the water was marked on the neck with a diamond as zero, the graduation was then proceeded with by withdrawing the water half a cubic centremetre at a time, and marking on the neck the height of the water as

each half c.c. was withdrawn. The neck being graduated in this way, it was possible to note immediately before displacing the disengaged gas, which was done over distilled water, the volume of water which would enter the flask and become mixed with its contents; the capacity of the flask, with the stopper inserted, and the composition of the gases dissolved in the distilled water being known, it was in this way possible to calculate and correct for the error which the admission of the distilled water into the flask would introduce in the estimation of the dissolved gases in the liquid under experiment.

The form of apparatus which I have used for extracting the dissolved gases, measuring and analysing them, is shown in the accompanying drawing. It consists of a mercury-pump combined with a gas analysis apparatus, and can be used for all three operations required in the examination of the gases dissolved in liquids, viz. for their extraction, measurement, and complete analysis. The remaining parts of the apparatus which are shown in the sketch consists of a Liebig's condenser of glass, and a round-bottomed stout glass flask with a side tube from the neck.*

The flask, which for convenience of reference I propose to name the laboratory flask, is made of sufficiently stout glass to bear a vacuum. The only points of importance, so far as shape is concerned, are that it must be round-bottomed, and that the neck must be somewhat long and tapering to allow of the short india-rubber cork, by which the inner tube of the condenser is packed air-tight into it, fitting sufficiently deep down to leave a space above itself for a water or mercury luting.

The capacity of the flask should be about four times the volume of liquid to be boiled in it. It is convenient to have two sizes, viz. 1500 c.cs., and 2500 c.cs.

The laboratory flask is employed for conducting the necessary operation of boiling the liquid under examination in vacuo, for the extraction of the gases dissolved in it. Since the condenser to which it is attached cools down, and condenses the aqueous vapour given off during the process of boiling, the liquid may be heated to violent ebullition continuously for any required length of time without fear of unduly raising the pressure of the vapour and gases in the flask.

The gas analysis apparatus proper, shown in the drawing, is an improved form of that which I have already described in a Paper, published in the "Scientific Proceedings of the Royal Dublin Society."† To that Paper I would

* The glass parts of the apparatus were obtained from Messrs. Baird and Tatlock, of Glasgow and London.

† "On an Apparatus Applicable for Gas Analysis and Other Purposes."—Scien. Proc. R. D. S., vol. vi., pt. ix., p. 555 (1890). Reprinted in the "Chem. News," 62, pp. 196–199, and 204–206.

refer for a more complete description of the principles of the apparatus and its applicability to other operations than that here described.

In this Paper I will only give a short description of the apparatus shown in the drawing, sufficient to explain the improvements which has been made on the older form, and to render intelligible the use of the apparatus for the purposes of this research.

Its essential parts are a gas burette and laboratory vessel, differing in many respects in form and use from those generally employed in other forms of gas-analysis apparatus, and a long pressure-tube provided at its upper end with a Friedrich's patent glass stopcock.

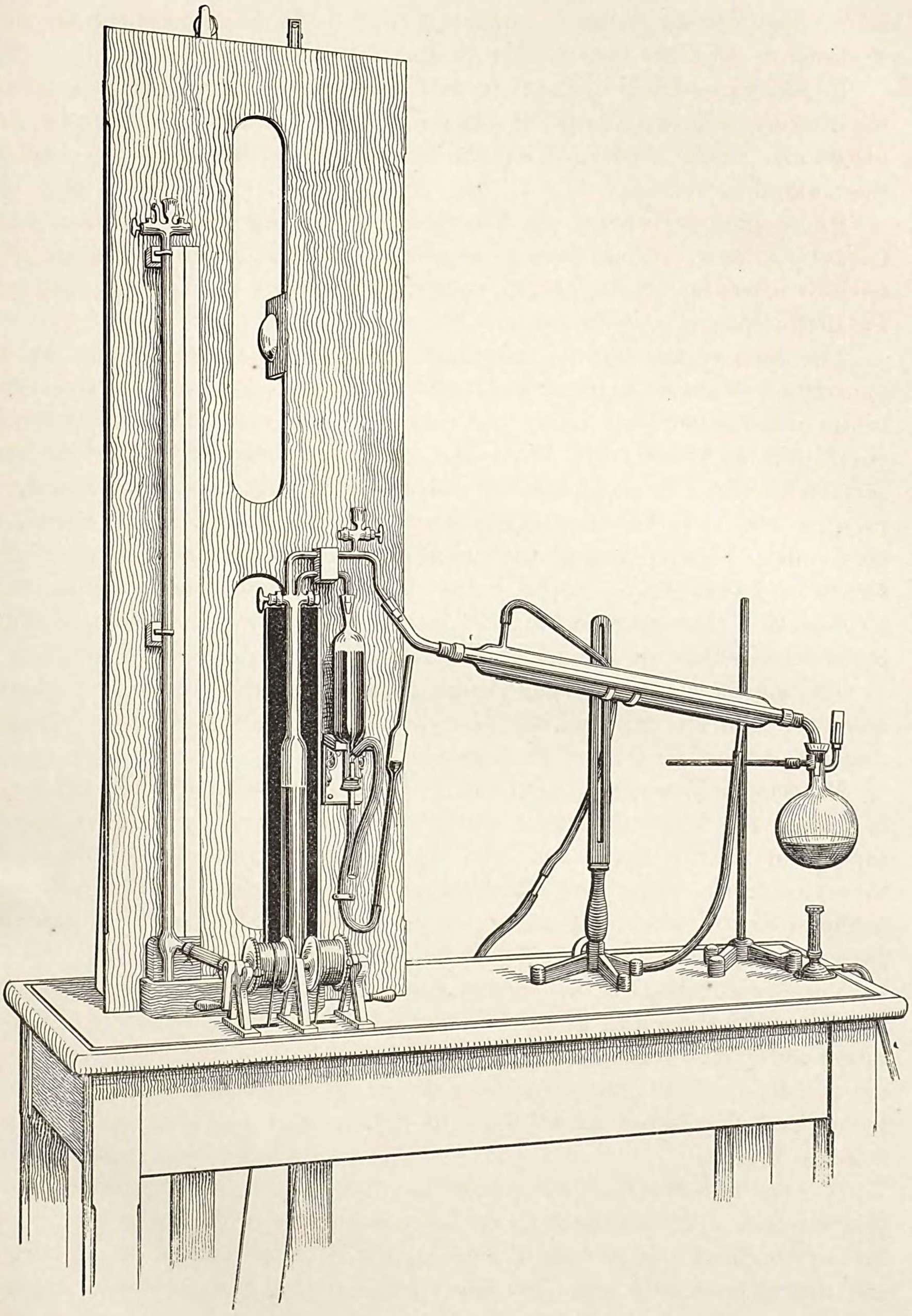
The form of the burette is exactly similar to that employed in my older apparatus. It is contracted at its lower end, and passed through a hole cut in the centre of the indiarubber bung which closes the lower end of the glass cylinder, enveloping the burette, and which thus provides a means of keeping the burette surrounded with a water-jacket. It is then bent at right angles, and joined to the pressure-tube by indiarubber tubing lined with canvas, and tightly wired to the glass tubes. The bottom of the cylinder, the joint and bent portions of the burette and pressure-tube sit in a trough cut out, and suitably shaped from a piece of solid mahogany, and which, during work, is kept filled with mercury to protect the indiarubber joint from the air.

The way in which the glass cylinder, burette and pressure-tube are supported is indicated in the drawing, but this will be more clearly understood from the drawing of the older form of the apparatus.

The supply of mercury to the burette and pressure-tube is regulated by means of a reservoir, which rests in a wooden box, suspended by a catgut line, and capable of moving freely from the top of the apparatus to the floor. It is prevented from swinging by a grooved guide fixed to the back of the apparatus, in the grooves of which slide corresponding portions of the box. The catgut line passes over the necessary lead pulleys to the windlass mentioned below.

The reservoir box can be raised or lowered by a small winch or windlass fixed in front of the apparatus, as shown in the drawing, and fixed at any point by the rachet cut on one side of the winch drum. The flexible tube from the reservoir passes through a hole, cut in the wooden upright supporting the apparatus, at a point just below the level of the side branch from the pressure-tube, and is attached thereto.

It is essential that the flexible tube from the reservoir should be attached to the pressure-tube, and not directly to the burette, because, when the reservoir is kept for any length of time at a lower level than that of the bottom of the burette—and this is constantly necessary when employing the apparatus as a vacuum pump, or when measuring gases under very low pressure—there is a tendency



GAS-ANALYSIS APPARATUS.

for air to diffuse through the indiarubber tube. With this arrangement, if an appreciable quantity of air does thus diffuse during an experiment, it passes up into the pressure-tube when the reservoir is raised, and can be driven out when necessary through the stopcock at its upper extremity, without in any way affecting the experiment; as a precaution against the air being carried round into the burette by the inflowing mercury, the pressure-tube is expanded considerably where the side tube is attached to it, as shown in the drawing.

The upper end of the burette is provided with a Friedrich's patent two-way stop-cock, by means of which communication with the laboratory flask, or a laboratory vessel, to which it is connected by the branch tubes shown in the drawing, can be opened or closed at will.

The upper branch tube leading to the condenser and flask is 3 mm. bore; the lower branch is a capillary tube.

The two branch tubes are held against a wooden block, shown in the drawing, in cork-lined grooves, by a brass plate, also cork-lined, and screwed to the block. The grooves are made sufficient in width to allow of considerable play in a vertical direction.

This last precaution is necessary to allow for alteration in length of the burette induced by changes of temperature. When the tubes are properly fitted in these grooves, there is no danger whatever of their being broken, even if the apparatus is subjected to careless handling.

The contracted portion of the upper part of the burette is about 225 mm. long, and has a capacity of 15 c.cs., the wider portion being about 410 mm. long, with a capacity of somewhat more than 250 c.cs. Both portions are graduated, the former at intervals of one-tenth c.c., and the latter at intervals of 25 c.cs.

The pressure-tube has a working length of 1000 mm. above the level of the lowest division, viz. the 250 c.cs. line of the burette.

The height of the mercury in the pressure-tube is read by means of a millimetre scale etched on the unsilvered surface of a narrow slip of looking-glass, which is fixed to the back of the apparatus, close to the pressure-tube, at such an angle as to reflect the image of the tube through the portion of the glass bearing the scale. To read the height of the mercury in the tube, the eye is held a little to the right of the scale, and moved about until the scale-lines in the immediate vicinity of the reflected image of the mercury meniscus coincide with their own images reflected from the silvered surface of the glass. When the eye is in this position, the height of the mercury in the tube can be accurately read to 0.5 mm.

The laboratory vessel differs in principle and shape from that used in Frankland's and M'Cleod's apparatus. Its shape is shown in the drawing; the lower end, which is cylindrical in shape, is 25 mm. diameter, and 55 mm. long, and is furnished with a side tube for connecting the vessel with a separate

reservoir. The middle portion of the vessel is 160 mm. long, and the upper end has an inverted conical shape, which is 55 mm. long, the diameter increasing from 3 or 4 mm. at the lower, or narrow part, to 20 mm. at the mouth.

Two platinum wires are sealed into the vessel in the position shown in the drawing.

The special shape given to the upper portion of the laboratory vessel enables it to be easily connected, or disconnected with the burette. When the vessel is placed in position, as represented in the drawing, the capillary branch tube, the end of which is fitted with an indiarubber collar, tightly closes the narrower part of this portion of the vessel, while the lower shoulder of the vessel rests upon a shelf (shown in the drawing) which has somewhat the shape of a horseshoe. If the space above the rubber collar at the end of the branch capillary tube be filled with mercury or water, a perfectly air-tight joint is obtained. The joint may, in fact, be made so staunch, that a vacuum can be maintained in the vessel, or, on the other hand, explosions may be made therein without fear of loss.

When it is desired to disconnect the laboratory vessel, its lower portion is drawn forward sufficiently to clear the shelf, and it is then lowered to detach it from the branch tube from the burette.

By reversing these movements, the laboratory vessel may be again placed in its position. The shape of the indiarubber collar is of importance; its lower end must be shaped so as to bear well on the sides of the contracted portion of the laboratory vessel. The collar is easily given the necessary shape by means of a red-hot iron wire. The lower end of the laboratory vessel is closed by a well-fitting cork, through the centre of which passes a straight glass tube about 10 mm. long and 3 mm. bore; to the outer end of this a piece of stout indiarubber tubing, about 15 c.ms. long and 1 mm. bore, is attached.

When the cork is fixed into its place, the other end of this glass tube projects into the laboratory vessel for about 2 ctms. A small Bunsen screw-clamp is provided, with which to open or close the rubber tube when necessary.

The glass tube supplies the means of introducing gaseous or liquid reagents into the laboratory vessel, and I therefore purpose to call it the reagent tube.

The side tube from the lower portion of the vessel is, as I have already stated, connected by means of a rubber tubing, with a separate reservoir, which is supported in a box,* and raised or lowered along guides fitted at the back of the apparatus, by means similar to those already described as provided for the reservoir to the burette.

The shelf which supports the laboratory vessel is, in reality, a small bracket, the vertical limb of which is provided with a tongue at the back, sliding in a

* The position of this box is not quite correctly shown in the drawing. Its true position will, however, be understood from the description in the letter-press.

groove cut in the wooden back of the apparatus, so that, thus guided, it can be moved up and down in a vertical direction, and clamped at any point by a thumb-screw, so as to adjust the amount of pressure which the upper end of the laboratory vessel will exercise on the rubber collar.

This adjustment provides for all alteration, either in the length of the laboratory vessel, owing to changes of temperature, or in the size of the rubber cork, owing to wear or replacement, and ensures an air-tight joint with the capillary tube from the burette at all times.

The whole apparatus is supported on a strongly-made table, 91 ctms. high.

The method of working the apparatus is as follows :—The pressure-tube, burette and laboratory vessel being filled with mercury, and all stopcocks closed, the laboratory vessel is placed in its position in the manner just described. The laboratory flask, into which 50 c.cs. of pure distilled water have been placed, with or without the addition of 1 or 2 c.cs. of pure sulphuric acid, as the experiment may require, has been placed, is fitted to the end of the condenser. The water in the flask is then boiled, the air and steam escaping through the side tube in the neck of the flask. The end of this tube is fitted with a short piece of indiarubber tubing. After continuing the boiling for about ten or fifteen minutes, the burner is removed from under the flask, and at the same time the short rubber tube, attached to the side tube from the neck, is closed with a piece of glass rod.

By this operation the flask is largely freed from air; the air still remaining in it, and in the condensing tube is next drawn off by working the apparatus as an air-pump. This is done by lowering the burette reservoir to its lowest limit, the mercury flowing out of the burette, leaving it in vacuo. If now the stopcock of the burette be turned to open communication between it and the laboratory flask, aqueous vapour and portions of the residuum of air left in the flask will pass into the burette. The stopcock is then turned to close communication with the laboratory flask, and the reservoir raised to refill the burette with mercury. The air and water drawn into the burette by this operation are then passed into the laboratory vessel by opening communication therewith. By this time the neck of the flask and the side tube therefrom will be sufficiently cooled to allow of water being safely poured into the space left in the neck above the rubber cork, by which the condensing tube is fitted into the flask, to protect it from the air, and to fit a water-jacket over the piece of rubber tubing closing the side tube.

The operation of drawing aqueous vapour and gases from the laboratory flask into the burette, and driving them thence into the laboratory vessel is repeated until the mercury, or rather the condensed water on the top of the mercury, strikes the closed stopcock of the burette with a sharp metallic click when the burette becomes full of mercury. In this way the burette provides an extremely

sensitive means of gauging the degree of exhaustion which can be obtained in the laboratory flask. The flask is usually exhausted by the time the burette has been filled with mercury, and emptied four or five times. The flask being exhausted, preparations are immediately made to transfer a known volume of the water to be examined, into the laboratory flask.

A few minutes' delay is first allowed to allow the surplus water left on the sides of the burette to collect at the top.

This is then transferred to the laboratory vessel, which is next detached from the capillary branch tube, care, however, been taken before doing so, to leave the branch tube full of mercury.

The rubber collar is detached from the end of this tube, which is then connected by means of a piece of indiarubber tube with a glass tube of the same thickness and bore as itself (27 ctms. long), which has been previously completely filled with the water to be examined. The lower end of the latter tube is immersed in the water for examination, the burette reservoir lowered a little, and the stopcock opened, the water then passes into the burette.

By gradually lowering the reservoir, 250 c.cs., or a less volume if required, of the water may be drawn into the burette.

When this has been effected, the stopcock is closed, and opened to the laboratory flask. The water then passes into it from the burette, care being necessary to prevent mercury getting into the flask during the operation. The glass tube is now detached from the capillary branch, the rubber collar reattached, and the laboratory vessel refixed in position. It is now necessary to clear the laboratory vessel of small bubbles of air, and of any decided quantities of water that may remain on its sides or in the reagent tube from the process of washing after the previous analysis. This is rapidly done by raising the reservoir decidedly above the level of the side tube of the vessel, and unscrewing the clip which closes the rubber tube attached to the outer end of the reagent tube, so as to allow mercury to pass into the pipette attached to the other end of the rubber tube and supported by a clip, fixed to the stand, in the position shown in the drawing. The reservoir is then dropped considerably, and the screw-clip being cautiously opened, the greater portion of the mercury in the pipette is drawn back into the laboratory vessel, carrying with it any air-bubble or water which may have lodged in the reagent tube. The clip being closed, the reservoir is raised sufficiently to cause the mercury to overflow the laboratory vessel when it is slightly withdrawn from the rubber collar on the capillary branch tube, thus driving out the air and water from the top of the vessel. The laboratory vessel is refixed in position, and the reservoir is then lowered so as to empty the vessel almost completely, and being rapidly raised, note is made as to whether the sharp click is heard when the vessel refills completely. If not, it is

again partly detached from the collar, and some mercury driven out, and the vessel again replaced in position. These operations of causing the mercury to overflow the top, lowering the reservoir so as to nearly empty, and again rapidly refilling the vessel, are continued till the sharp click, indicative of complete exhaustion, is obtained. Generally, this is obtained after two or three trials, the operation being extremely easy.

During the time occupied in these manipulations, the water in the laboratory flask is kept violently boiling to disengage the dissolved gases.

These are drawn into the burette from the flask, and stored in the laboratory vessel in a similar manner to that described for exhausting the flask in the first instance, with the exception that the condensed aqueous vapour, drawn into the burette with the dissolved gases, is not allowed to pass into the laboratory vessel, but is returned to the flask. When the dissolved gases have been completely extracted, a few minutes delay are allowed for the small quantities of water, adherent to the sides of the burette, to rise to the top, when it is returned to the flask. The measurement and analysis of the gases stored in the laboratory vessel is then proceeded with.

The method of adjusting the level of the mercury in the burette, after the gases have been passed into it, will require some explanation. The simple plan of closing the stopcock, and then raising and lowering the reservoir so as to bring the mercury to the level of the division line selected cannot always be followed, since, after transferring the gas, a small bubble of it sometimes remains in the laboratory vessel under the rubber collar, and cannot be removed therefrom. When, therefore, the level of the mercury in the burette is being adjusted, the stopcock must be left open, and the adjustment be made by working the two reservoirs conjointly. To transfer the gases into the burette in the first instance, its reservoir is lowered, and that of the laboratory vessel is raised, if necessary, until nearly all the gas is passed over, a little, however, remaining in the laboratory vessel. It must be observed at this point whether the gas will require to be compressed or expanded in order that the mercury in the burette shall stand, after final adjustment, at the level of the division line selected for measurement, and in order that, at the same time, the laboratory vessel shall be completely filled with mercury, with the exception, possibly, of the small bubble of gas above referred to; with careful manipulation, however, no bubble of gas need remain. With a little practice, the adjustment may be effected easily and quickly. An indication that all the gas possible has been transferred to the burette at the final adjustment, is obtained when the mercury, or more generally water, since a small quantity always collects in the labortatory vessel during the operation of extracting the gases from the laboratory flask, and storing them, as above described, rises a little in the capillary branch tube.

When the necessary adjustments have been made, the height of the mercury in the pressure tube, which, I should here note, is kept moist, is read off, the line of measurement on the burette and the temperature of the water in the jacket, are also noted. The next step is to absorb the carbon dioxide; the small quantity of solution of potassium hydrate required for this purpose is introduced into the laboratory vessel thus:—the stopcock of the burette is closed, the reservoir of the laboratory vessel is fixed well above the level of the reagent tube, and a pipette containing the solution of potassium hydrate is connected to the free end of the rubber tube attached to the reagent tube, and then left supported, as indicated in the drawing.

As the reservoir is now above the level of the reagent tube, on unscrewing the clamp the mercury will flow into the pipette, and expel any small bubble of air that may have been left in the open end of the rubber tube after attaching the pipette to it. The air having been completely expelled, the clamp is screwed up again, and the reservoir dropped to a level a little below that of the reagent tube.

On carefully opening the clamp the mercury in the pipette will slowly flow back into the laboratory vessel, and after it the required amount of potash solution, care being used so as not to empty the pipette entirely. As soon as this is accomplished, the clamp is closed, and the reservoir raised to about its former level. The surplus quantity of solution remaining in the reagent tube may now be driven back into the pipette, and after it a little mercury, by carefully opening the clamp, which is closed again immediately this has been done. To effect the absorption of the carbon dioxide by the potash, the gas is passed into the laboratory vessel, and then backwards and forwards into the burette three or four times, care being taken not to allow any of the potash into the burette. In about five minutes the carbon dioxide will be completely absorbed, and the remaining gas again measured just as before, and the height of the mercury in the pressure tube noted, the difference of reading before and after absorption giving the pressure exerted by the carbon dioxide at the volume at which the gases have been measured.

If the volume of this gas has been large, it will reduce the errors of reading in the further process of analysis, if the remaining measurements be made at a volume less than that which was necessary before absorbing the carbon dioxide. The operation of absorbing the oxygen by means of pyrogallic acid is carried on similarly to that for absorbing the carbon dioxide. The remaining gas will consist, at least in most cases, of pure nitrogen. Its pressure at the volume at which the measurements for the determination of the oxygen were made, is easily determined by deducting from the last noted pressure the height of mercury in the presure tube corresponding to the height of mercury in the burette at the line

at which the measurement for the determination of the oxygen was made. This height may be quickly determined for each experiment by noting the height of mercury in the pressure tube, when the mercury in the burette is adjusted at the said line of measurement in vacuo.

The residual gas, after the absorption of the carbon dioxide and oxygen, may, in some cases, contain hydrogen, and possibly marsh gas.

When this is the case the following procedure is adopted :—

After carbon dioxide and oxygen have been absorbed and determined, the remaining gases are driven back into the laboratory flask, and the laboratory vessel and burette are very carefully cleaned.

To do this the reagents in the laboratory vessel are driven gradually above the rubber collar on the end of the capillary branch tube by lowering the vessel a little from the collar, and carefully raising its reservoir. As the reagents rise above the collar they are absorbed by means of blotting paper. When the vessel has been cleansed by this means as far as possible, it is replaced in position, and about 50 c.cs. of dilute sulphuric acid (1 : 3) are introduced into it through the reagent tube. A little of the acid is allowed to rise above the rubber collar to neutralize the potash adherent to it, and the remainder is drawn into the burette.

The laboratory vessel is then completely detached from the capillary branch tube, and the acid, after having been drawn down nearly to the bottom of the burette, is discharged from it into a beaker.

The laboratory vessel is next placed in position and filled with tap-water through the reagent tube, and a similar series of operations again carried out as above described, with the view of washing both vessel and burette free from acid ; the washing is repeated two or three times with distilled water.

When the operation of washing has been completed, the liquid in the laboratory flask is boiled, and the gases drawn from it into the burette and laboratory vessel, with the precaution previously described for their complete expulsion. After their measurement, some pure oxygen is introduced into the laboratory vessel through the reagent tube in a manner exactly similar in principle to that above described for the introduction of liquid reagents. The mixed gases and oxygen are then measured, and exploded under reduced pressure, and the further analysis proceeded with in the ordinary way.

Since the water surrounding the burette becomes unequally heated during the process of extracting the gases from the laboratory flask, it is necessary to replace it before measuring and analysing the gases. This is readily done by syphoning off the water immediately after the process of exhausting the flask has been completed, and replacing it with some that has been exposed for some time to the temperature of the laboratory.

I ought to note, before concluding this description, that it has been ascertained by experiments, which are detailed in my Paper on the earlier form of the apparatus already referred to, that the bubble of gas, which is sometimes retained in the laboratory vessel during measurement, does not introduce appreciable errors therein.

Extraction of the Gases in Solution.

Although it is impossible to completely exhaust a water of the gases it holds in solution in vacuo in the manner I have described, it is nevertheless possible to carry the exhaustion so far that the quantities of the respective gases left behind in the water may be disregarded, as experience has shown that they do not appreciably affect the results.

Both oxygen and nitrogen are readily extracted from the water, and transferred to the laboratory vessel for measurement by three or four exhaustions of the flask during the boiling of the water in it, but the carbon dioxide is not so easily disengaged, and between a quarter and half an hour's ebullition in vacuo is usually necessary to effect its removal, the length of time depending on the quantity of this gas in solution, and also, apparently, upon the dissolved mineral matters also, a hard water requiring more boiling than a soft one.

Owing to the slowness with which bicarbonates decompose when boiled, I have found it practically impossible to determine, separately, the "combined" and "nncombined" carbon dioxide in a water. But the total carbon dioxide is readily estimated by boiling the water with a suitable acid, and by the term carbon dioxide I shall hereafter always include the combined carbon dioxide with that which may be held in solution uncombined.

The acid I have used for this purpose has invariably been sulphuric acid. When its presence has been necessary, I have always added it to the water placed in the flask in the first instance, preparatory to exhausting the air from the flask, as already described.

The presence of the acid does not interfere with the determination of the oxygen and nitrogen, unless, of course, nitrites are present in the water. When this is the case, the dissolved oxygen and nitrogen are determined in the absence of acid, and the carbon dioxide afterwards estimated by a separate experiment in the presence of acid.

I have generally employed 250 c.cs. to 500 c.cs. of a water for the analysis of the dissolved gases; such volumes of water giving suitable volumes of gases for the apparatus. The operation of extracting and analysing the dissolved gases in a water may generally be completed within two hours.

Methods employed for the determination of Inorganic Nitrogen.

The nitrogen as ammonia has been determined in the ordinary way by nesslerizing after distillation, with the exception of a few cases, when it was necessary to directly nesslerize without previous distillation, owing to the fact that the substances experimented with were decomposed on boiling.

The method employed for estimating the nitric acid was that which has been worked out by Williams,* and which depends upon the action of a "zinc-copper couple" in reducing nitrates and nitrites to ammonia. My general experience with this method is, that it gives reliable results.

For the estimation of nitrous acid, I have employed Griess' metaphenylene-diamine method, as detailed in Sutton's "Volumetric Analysis," p. 367, 5th edition.

Wherever possible, that is when the total quantity of inorganic nitrogen has not been large, I have preferred to subject the water to the action of the "zinc-copper couple" before distilling off the free ammonia present.

The nitrogen as free ammonia then obtained, after the action of the couple, represents the total inorganic nitrogen. This amount, less that as free ammonia originally present, and nitrous acid, which are separately determined, gives the nitrogen present as nitric acid.

When, however, the free ammonia or nitrous acid is present in large quantity, I have separated them in the ordinary way, the free ammonia by distillation, and the nitrous acid by distillation in the presence of an excess of ammonium chloride, before examining the water for nitric acid. I have occasionally employed Crum's method with Lunge's nitrometer to check the results obtained with the zinc-copper couple method, and have usually obtained concordant results therewith.

Errors.

The methods of experiment which I have described are liable to three distinct sources of error. They are:—

1. The possible changes in volume which the dissolved gases may suffer during the manipulation necessary for bottling the water, and transferring it to the gas analysis apparatus.

2. The operations in the gas analysis apparatus, viz. the extraction and analysis of the dissolved gases.

* C. S. J., 1881, 100.

3. The changes of temperature which the solutions undergo during the time of keeping them in bottles, as described, out of contact with air.

It would be difficult to give a precise value for each of these three sources of error, but their total effect upon the final results obtained, which are, it must be remembered, the differences between the determinations for each dissolved gas before and after keeping the liquid under the prescribed conditions, will be found approximately indicated in the majority of the experiments which I shall describe in this Paper, by the atmospheric nitrogen determinations.

Since most of my experiments have been carried on under more or less aërobic conditions, the atmospheric nitrogen has not, except apparently in a few cases, suffered changes in common with the other bodies with which it has been associated. The difference between the volume of this gas before and after fermentation, therefore, affords a very valuable index of the extent to which the above possible sources of error affect the analytical results.

The total error may also be found practically by blank experiments with the water employed for making up the solutions.

I have usually found the difference between the determination of the volumes of nitrogen before and after keeping to be under 0·2 c.c. per litre of water. In some cases it has risen nearly to 0·3 c.c., but this is exceptional.

Blank experiments with tap-water, the particulars of which will be given later on with the details of my other experiments, show that the oxygen determinations before and after keeping do not usually differ by more than 0·1 c.c., and rarely differ by as much as 0·15 c.c. per litre of water.

The error attending the determination of carbon dioxide varies somewhat with the quantity, and probably also with the composition of the mineral matter in solution in the water. When the quantity is not greater than 40 or 50 c.cs. per litre, the error is about the same as that affecting the nitrogen determination, but, as the quantity increases, the error is liable to slowly increase also, and may reach to as much as 1·0 c.c. per litre for quantities amounting to 200 c.cs. per litre. In the case of a hard spring water in which the carbon dioxide reached to nearly 300 c.cs. per litre, the determinations of this gas before and after keeping showed differences of as much as 2 c.cs., although the atmospheric nitrogen and oxygen determinations were similar, and indicated that no fermentation had gone on therein during the time of keeping it. In consequence of this, I have avoided, when possible, the presence of any large quantity of carbon dioxide, and have employed sodium carbonate only, when it was necessary to add a carbonate to my test solutions.

The errors of the gas analysis apparatus are very small, and need not be discussed, since I have dealt with them in the Paper already referred to, describing the earlier form of the instrument.

It will be seen from the foregoing remarks, that, although the method is open to several sources of error, it is possible to keep the total error within such narrow limits that valuable results may be obtained by it. But in order to effect this, it is necessary to observe certain precautions in carrying out some of the steps in the method, and to these precautions I will now briefly refer.

The Preparation and Analysis of the Solutions and Dilutions.

In the first place the tap-water employed was that supplied to Dublin from the Vartry Waterworks. It is a good upland surface water, and has proved a valuable one for the purposes of my experiments, since it contains extremely small quantities of dissolved matters, the total solids being usually not more than four parts per 100,000 of water. It, however, invariably contains small quantities of peaty colouring matter, and for this reason I have sometimes found it necessary to use pure distilled water instead. The water was drawn from a large cistern holding nearly 400 gallons.

When making up a long series of dilutions for observation, it has, of course, been impossible to determine the gases in each member of the series just before bottling, since the time required for so many analyses would be so considerable that it would be impossible to prevent serious changes of temperature, and also, in all probability, fermentative changes, especially if sewage-water happened to be the subject of experiment, and the final results would therefore not be comparable. When dealing, therefore, with a series of dilutions at the commencement of an experiment, I have determined the dissolved gases and inorganic nitrogenous bodies in the lowest dilutions, and in the tap-water employed for making the dilutions, only, and calculated, from the data obtained, the quantities of dissolved gases and inorganic nitrogenous substances for all the other dilutions made up. I need scarcely remark that at the conclusion of an experiment each member of the series of dilutions has been in every case directly analysed.

I have adopted a similar method of preparation for all the dilutions I have experimented with. The basis of each series of dilutions has been either undiluted sewage-water, or a strong solution of other substances of known composition and strength. Five litres, at least, of the lowest dilution have been made, and aërated by violent agitation with air in a large glass vessel fitted with a glass tap. After the aëration the solution has been allowed to rest for about fifteen minutes, to allow air-bubbles to rise to the surface and escape.

Two or more bottles have then been carefully filled, and allowed to stand unstoppered for a few minutes, until again all air-bubbles have escaped. All the

bottles, with the exception of one, were then carefully stoppered, and placed neck downwards in distilled water. The one left unstoppered was at the same time transferred to the gas analysis apparatus, and the volume of the liquid required for the analysis then drawn from it into the burette of the apparatus, and thence passed into the laboratory flask, and boiled in vacuo.

Immediately this had been done, the preparation of the remaining dilutions required is proceeded with in an exactly similar manner, except that portions of them were not reserved for analysis.

When all the dilutions have been made, five litres of tap-water were placed in the same glass vessel, and agitated with air just as in the case of the dilutions. The water after aëration is drawn off into bottles and preserved in the ordinary way, a portion, as in the case of the lowest solution, being transferred to the gas analysis apparatus. With the aid of an assistant, the analysis of the lowest dilution and the preparation of all the required dilutions may be completed within two hours, when the aëration, bottling, and analysis of the tap-water may be proceeded with without delay.

The chief point of importance to be attended to in the preparation of these dilutions is that of temperature; it should be the same for each dilution. This is not difficult to accomplish when the tap-water is drawn from so large a cistern as that which has furnished my supply. I have also taken the precaution of tying up the ball-cock of the cistern when making up the dilutions.

The complete aëration of the dilutions is also of importance; but, with a good tap-water such as I have employed, this condition can be attained without difficulty.

In all my experiments I have endeavoured to keep the variation of temperature from that obtaining at their commencement within as narrow limits as possible, and as a result of this I have found it unnecessary to make any correction for expansion or contraction of the liquid arising from change of temperature, the errors arising therefrom being very small in comparison with those from other sources; thus the maximum difference between the initial and final temperature of any of the experiments I shall quote in this Paper has been within 12° C., viz. from 8° C. to 19° C. A litre of water, on rising from 8° C. to 19° C., would increase (according to the data given in Muir and Morley's edition of "Watt's Dictionary," vol. iv., p. 861) in volume by 1·409 c.cs. Such an alteration in volume, it will be seen from the details of my experiments, gave rise to so small an error in comparison with others which affected them that it was thought unnecessary to make any correction for it.

The errors arising from the tendency to disengagement of the dissolved gases on variation of temperature would of course be very large, and in fact would render the results valueless had not the precaution already described been taken

to prevent the escape of the disengaged gases from the bottle in which the solution was kept.

The conditions which give rise to the maximum disengagement of gases from liquids kept in bottles, in the manner I have already explained when describing the method of experiment adopted, and apparatus employed for this investigation, are, first, a considerable rise of temperature above the initial point, during which the liquid will expand, and small quantities of it be forced out of the bottle between the neck and the stopper, followed by a considerable fall, when the liquid will contract, and, if the stopper be well ground, a small space will be formed in the bottle containing gases previously dissolved, and will be more or less steadily maintained, since the bottle is immersed in water, neck downwards, so long as the temperature remains below the maximum point to which it was formerly raised. The relation between the quantity of each gas disengaged in this way to that remaining in solution will practically vary with the temperature, according to Henry's law.

As a practical illustration of the influence of variation of temperature upon solutions kept under the conditions described, I may here give an extreme case, viz. an experiment with tap-water kept for a period of fourteen months.

This experiment was started on the 2nd February, 1893, when the tap-water before bottling was violently shaken up with air in a large vessel. After this operation the water was allowed to stand until quite free from air-bubbles. Its temperature was then found to be 10° C. A bottle was carefully filled with a portion of the aërated water, another portion being immediately afterwards transferred to the laboratory flask of the gas analysis apparatus. On April 3rd of the following year the contents of the bottle were examined. A bubble of gas, about 6 c.cs. in volume, was found to have been formed. The gases in the bubble were collected over fully aërated distilled water, and immediately afterwards transferred to the laboratory vessel of the gas analysis apparatus, measured, and analysed; the water in the bottle was not examined until next day, in order to allow time for the distilled water, which had replaced the disengaged gases, to diffuse equally through it. During this time, it need scarcely be said, the bottle was kept immersed in water.

The temperature at the conclusion of the experiment was 13°·8 C.

The results of the analysis of the disengaged gases were as follows:—

Total volume at 0° C. and 760 mm. Bar, ...	5·8414 c.cs.
Volume of oxygen ,, ,, ...	1·0058
Volume of nitrogen, ...	4·8356
Volume of carbon dioxide, ...	0

The capacity of the bottle was 2530 c.cs. Dividing the volumes of oxygen and nitrogen by 2·53, we get the volumes of these gases disengaged, per litre of water, at the time of the conclusion of the experiment. These volumes are :—

Oxygen, ...	0·40 c.cs.
Nitrogen, ...	1·91

The results of the analysis of the gases* dissolved in the water at the commencement and conclusion of the experiment are given in full in the following Table :—

—	CO_2.	O_2.	N_2.	N as NH_3	N as N_2O_5
At commencement, ...	4·04	7·8	15·60	0	0·0001
At conclusion, ...	4·94	6·23	13·60	0	0·0008
Correction for disengaged gases, . .	0	0·40	1·91	—	—
Corrected vols., ...	4·94	6·63	15·50	—	—
Differences, ...	+ 0·90	− 1·17	− 0·10	—	+ 0·0007

No correction was made for the distilled water introduced into the bottle when collecting the disengaged gases.

The changes in volume of the carbon dioxide and oxygen shown in the above Table were no doubt due to the fermentation of small quantities of peaty colouring-matter which the tap-water contained, and not to experimental errors. This explanation is supported by the increased quantity of nitrate found in the water after keeping.

The gaseous nitrogen, however, remained unchanged in volume during the period of keeping, and the difference between the volume of this gas found before and after keeping indicates the probable value of the total error from the two distinct sources mentioned above.

Before leaving the consideration of errors due to variation of temperature of the solutions during the time of keeping them, I ought perhaps to point out that a disengagement of dissolved gases on rise of temperature is more or less completely prevented under the ordinary conditions of my experiments, since a considerable pressure was always kept up in the bottles when the temperature was rising, by keeping them resting with their full weight upon their stoppers.

This I have generally found sufficient to prevent the stoppers from becoming too freely loosened by the expanding force of the water under the influence of rise of temperature. I should add that care has been taken to guard the solutions against any serious daily variations of temperature, and the precaution of re-tightening the stoppers from time to time has also been taken.

* Volumes of the gases are expressed in c.cs., at N.T.P., per litre of water.

PART I.

Experiments with easily Fermentable Matters.

As I have already explained when describing the method of experimenting adopted, the experiments which I have now to record have for the most part been carried out with sets or series of dilutions, varying in strength, of comparatively strong solutions of polluted waters, such as sewage-water, or of other fermentable substances, including those which ferment with ease, and those which ferment with difficulty.

The details and results of the experiments are given in full in Tables, a separate Table to each set or series of experiments. Each Table, therefore, furnishes a fairly complete view of the nature and amount of the chief substances produced by the action of the mixed organisms natural to the solution or dilution during a fermentaton, carried on under conditions varying within narrow and well-defined limits, as well as the quantity of oxygen consumed in the process.

The information given in these Tables will, therefore, be found sufficiently full to render them self-explanatory.

But it will be necessary to discuss the results in some of the Tables at some length in order to indicate the typical results, which the method of experimenting employed can afford, and the general conclusions which can be drawn therefrom. The remaining Tables will be found to furnish additional experimental results, all tending to confirm those specially referred to.

It will be convenient to discuss, in the first place, the experiments with easily fermentable organic matters; and this I now propose to do, not necessarily in chronological order, but as they best illustrate the points which have to be considered.

My first definite series of experiments was commenced on November 5th, 1891, and they were made with a sample of raw sewage collected from a main sewer at Monkstown, a residental suburb of Dublin. The sample of sewage was filtered through ordinary filter-paper to separate the matters in suspension as much as possible, and aërated, and the following dilutions were made from it with tap-water:—one volume of filtered sewage to 9, 19, 29, 39, 49, 59, 69, 79, 89, and 99 volumes of tap-water.

In the following, and all succeeding Tables giving the details and results of experiments, the dissolved gases are expressed in c.cs., at 0° C., and 760 mm. bar., and the inorganic nitrogen in fractions of a gramme, per 100 c.cs., of solution.

Under the columns headed I. and II. are given the results of analysis, before and after fermentation, respectively.

[TABLE I.

SERIES I.—COMMENCED 25TH NOVEMBER, 1891.

TABLE I.—*The Volume of Gases, and the Weights of Ammoniacal and Nitric Nitrogen, in the Mixtures of Sewage and Tap-Water, employed in Series I. of Experiments, before and after Fermentation.*

[The gases are expressed in c.cs., measured at 0° C., and 760 mm. bar.; the other constituents, as parts by weight, per 1000 c.cs. of liquid.]

Date of conclusion of Experiment.	Mixture.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_5 I.	N as N_2O_5 II.
1892. January 21	1 in 100	4·32	6·70	8·03	2·54	15·96	15·60	0·00062	0·00	0·00010	0·0010
	Differences, . .	+ 2·38		− 5·49		..	..	− 0·00062		+ 0·0009	
February 3	1 in 90	4·43	7·15	8·02	1·68	15·96	15·61	0·00067	0·00	0·0001	0·0012
	Differences, . .	+ 2·72		− 6·34		..	..	− 0·00067		+ 0·0011	
February 4	1 in 80	4·51	7·64	8·02	0·77	15·90	15·60	0·00077	trace.	0·0001	0·0012
	Differences, . .	+ 3·13		− 7·25		..	..	− 0·00077		+ 0·0011	
February 4	1 in 70	4·66	7·94	8·00	0·62	15·96	15·60	0·00086	0·00012	0·0001	0·0012
	Differences, . .	+ 3·28		− 7·38		..	..	− 0·00074		+ 0·0011	
February 5	1 in 60	4·81	9·18	8·00	0·48	15·97	15·68	0·0010	0·0008	0·0001	0·0008
	Differences, . .	+ 4·37		− 7·52		..	..	− 0·0002		+ 0·0007	
February 5	1 in 50	5·09	10·23	7·98	0·00	15·97	15·55	0·0012	0·0012	0·0001	0·0006
	Differences, . .	+ 5·14		− 7·98		..	..	− 0·00		+ 0·0005	
February 5	1 in 40	5·46	11·55	7·96	0·00	15·99	15·51	0·0015	0·0019	0·0001	0·0004
	Differences, . .	+ 6·09		− 7·96		..	..	+ 0·0004		+ 0·0003	
February 6	1 in 30	6·08	13·11	7·92	0·00	15·98	15·79	0·002	0·0032	0·0001	0·00
	Differences, . .	+ 7·03		− 7·92		..	..	+ 0·0012		− 0·0001	
February 11	1 in 20	7·31	18·56*	7·85	0·00	15·99	15·80	0·003	0·005	0·0001	0·00
	Differences, . .	+ 11·25		− 7·85		..	..	+ 0·002		− 0·0001	
February 11	1 in 10	11·03	26·40*	7·63	0·00	16·07	20·09†	0·006	0·0068	0·00	0·00
	Differences, . .	+ 15·37		− 7·63		..	..	+ 0·0008		0·00	
February 15	Tap-water, . .	3·58	3·45	8·07	8·00	15·95	15·82	0·00	0·00	0·0001	0·0001

REMARKS—Nitrous acid was not detected in any of the mixtures after fermentation. Mixtures 1/100 to 1/50 were quite inodorous after fermentation. 1/40 emitted an odour like that of rain-water. 1/30, 1/20, and 1/10 were very offensive.

* Each of these volumes include small quantities of SH_2.

† This volume includes CH_4 and H. The volume of these gases was not determined owing to an accident during analysis.

The foregoing Table illustrates very clearly the results which are obtained by the fermentation of dilutions of the same sewage-water under conditions gradually varying from those in which the atmospheric oxygen is in excess, relatively to the fermentable matters, to those in which the fermentable matters are in excess.

Solutions 1/100 to 1/80 afford an illustration of the influence of an excess of oxygen. In each of these solutions the fermentation has extended to the complete oxidation of the ammonia in the admixed sewage. In solutions 1/70 and 1/60 the conditions were evidently evenly balanced, for both a little free oxygen and a little ammonia were left in each. In solutions 1/50 and 1/40 the influence of gradually increasing quantities of fermentable matters in proportion to atmospheric oxygen is indicated by increasingly small quantities of nitrogen becoming oxidised, and by increasingly large quantities of ammonia left unoxidised. In solutions 1/30 and 1/20 we see that no oxidation whatever of nitrogen took place, and we notice for the first time that the volume of carbon dioxide begins to show a slight decrease relatively to the volumes of the gas formed in the more dilute solutions after fermentation. This is still more noticeable in the strongest solution 1/10. In this connection it is of interest to note that, simultaneously with the relative decrease in volume of carbon dioxide formed, bodies having offensive odours begin to make their appearance.

If we examine the contents of the Table a little more closely, we shall find that a number of important conclusions may be drawn as to the quantitative relationships existing between the amounts of atmospheric oxygen, and of fermentable matters originally present in the solutions on the one hand, and the products of fermentative changes on the other. These relationships become more apparent when each set of differences between the analytical results given in the Table for each solution are multiplied so as to make them comparable with one another. When so multiplied, the numbers may also be taken to represent the results which would have been obtained by experimenting with undiluted sewage, had that been possible, under the respective conditions represented by each dilution. In the following Table are given the products obtained by multiplying the differences in Table I. as described :—

[TABLE II.

TABLE II.

Solution.	Multiplier.	1. CO_2	2. N as NH_3	3. N as N_2O_5	4. O in c.cs. equiv. to N_2O_5	5. Sum of 1 and 4.	6. Vol. of O absorbed.
1/100	100	+ 238	− 0·062	+ 0·09	287	525	549
1/90	90	+ 245	− 0·060	+ 0·099	316	561	571
1/80	80	+ 254	− 0·062	+ 0·088	281	535	580
1/70	70	+ 230	− 0·052	+ 0·077	245	475	517
1/60	60	+ 262	− 0·012	+ 0·042	134	396	451
1/50	50	+ 257	0·0	+ 0·025	80	337	399
1/40	40	+ 244	+ 0·016	+ 0·012	38	282	318
1/30	30	+ 211	+ 0·036	0·0	0	211	238
1/20	20	+ 225	+ 0·04	0·0	0	225	157
1/10	10	+ 154	+ 0·008	0·0	0	154	76

The volume of oxygen given in column 4 as equivalent to the weights of N_2O_5 in the preceding column have been added for convenience of comparison; they have been calculated from the equation :—

$$2NH_3 + 4O_2 = N_2O_5 + 3H_2O.$$

This equation gives 3·19 c.cs., oxygen at N.T.P. as the volume required to oxidize 0·001 grammes nitrogen as NH_3 to N_2O_3.

Column 5 gives the sum of the volumes of carbon dioxide actually formed, and of oxygen theoretically equivalent to the nitric acid formed, and have also been added for comparison with the volumes of oxygen actually consumed.

The figures in the above Table, when allowance is made for errors, show that in the case of each of the solutions 1/100, 1/90, 1/80, in which the fermentation extended to the complete oxidation of ammonia, the quantities of carbon dioxide and nitric acid formed, and the volume of oxygen absorbed, were practically directly proportional to the quantities of fermentable matter originally present in them.

We also see that in all the other solutions down to 1/40, in which the sewage matters were gradually increased in relation to the dissolved oxygen, the volume of carbon dioxide formed was still directly proportional to the quantities of sewage matters originally present therein, and that the first effect of gradually increasing the proportion of sewage matters was the oxidation of relatively smaller quantities of ammonia; and as the proportions of sewage matters were still further increased, the ammonia began to be formed, instead of oxidized.

In the solution 1/40 the proportion of sewage-matters to dissolved oxygen was evidently pushed to its maximum. That is to say, the dissolved oxygen present was only just sufficient for the completion of the first stage of the fermentation of the organic matters, viz. the breaking down of the organic matters into carbon dioxide, water, and ammonia.

Hence, from the results of these experiments, if the fermentation of sewage matters really takes place in the two stages already referred to, we may tentatively conclude that when the dissolved oxygen is present in sufficient quantity for the completion of both stages, the quantities of carbon dioxide and nitric acid formed, and the volume of the dissolved oxygen absorbed, are directly proportional to the quantity of sewage-matters originally present.

If, however, the oxygen be not in sufficient quantity for the completion of both stages, but that of the first only, then the volume of carbon dioxide formed is still directly proportional to the quantities of sewage-matters originally present, and the oxidation of ammonia will or will not proceed according as there happens to be an excess or not of oxygen over and above that required for the first stage of fermentation.

In the solutions 1/30, 1/20, and 1/10 we have an insufficient quantity of dissolved oxygen for the completion of the first stage of fermentation. We then see a secondary, or an aërobic, fermentation sets in, in which the fermentation of the organic matter has been proportionally less and less complete as the quantity of sewage-matter increased. No simple relation between the carbon dioxide formed, and the quantity of sewage-matter originally present is apparent under this condition.

We may go further, and sum up the results given in the two Tables in a definite quantitative form, thus:—1000 volumes of the sample of sewage-water experimented with required 580 volumes of atmospheric oxygen, with a probable error of 15 volumes, for the complete fermentation of the fermentable matters, 280 volumes of which were required for the completion of the first stage, and 300 volumes for the second stage of fermentation. Or we may put it in another way, and state that when 1 volume of the sewage-water was mixed with 39 volumes of good river-water, fully aërated and fairly pure, at winter temperature, the oxygen dissolved in the river-water was sufficient for the first stage of fermentation; and, when mixed with 69 volumes, the supply of dissolved oxygen was sufficient for both stages of fermentation of the admixed sewage-matters. The atmospheric nitrogen determination for the solutions 1/100 to 1/40 inclusive, show greater differences than will be found usual. These may possibly not be due to experimental errors, but rather to "fixation" of atmospheric nitrogen during fermentation (see p. 587).

It should be noted that the tap-water used for diluting the sewage-water suffered but little, if any, change during the period of keeping.

Although the results afforded by this series of results were definite enough to warrant the conclusions I have formulated, they could not be considered as constituting a sufficient basis for extending these conclusions to polluted and natural waters generally.

Other waters, whether polluted with sewage-matters or vegetable matters such as peat, might contain fermentable substances of different composition, and organisms of different chemical functions; and such waters, when similarly examined, might give rise to results which might lead to different conclusions. It was therefore necessary to extend my observations to polluted and natural waters differing widely in character from one another.

I first, however, made some further experiments with other samples of sewage-water taken from the same locality as that from which the sample employed in my first series of experiments was taken. These confirmed the results I have already given, and need not be recorded here.

As examples of results obtained with sewage-water from quite a different locality, I will give those of two series of experiments with two samples, for which I was indebted to the kindness of Mr. J. C. Melliss, C.E., of London. Both samples were taken on June 21st, 1893, from the Richmond Main Drainage Works, near London, one being of raw sewage before treatment, and the other of sewage-water after clarification with lime and sulphate of alumina, and a very careful filtration through one of the gravel filter-beds with which the works are furnished. Each sample was an average of portions collected hourly from 6 A.M. to 6 P.M.

The raw sewage was filtered and aërated, and the following dilutions were made as before:—1 volume of raw sewage to 9, 19, 39, and 79 volumes of tap-water. The particulars of the experiments are given in the subjoined Table:—

SERIES II.—COMMENCED 24TH JUNE, 1893.

TABLE III.—*Experiments with Sewage- and Tap-water.*

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_5 I.	N as N_2O_5 II.	Remarks.
1893												
July 25	1 in 10	23·35	29·44	6·42	0·00	13·41	20·83*	0·0045	0·0047	0·00009	0·00	Solution very offensive after fermentation.
	Differences, . .	+ 6·09		− 6·42		..	..	+ 0·0002		− 0·00009		
July 26	1 in 20	14·21	19·78	6·44	0·18	13·41	13·49	0·00225	0·0025	0·00009	0·00	Solution free from odour after fermentation.
	Differences, . .	+ 5·57		− 6·26		..	..	+ 0·00025		− 0·00009		
July 26	1 in 40 †	9·64	12·45	6·46	3·16	13·41	13·49	0·001125	0·00115	0·0001	0·0001	Ditto.
	Differences, . .	+ 2·81		− 3·30		..	..	+ 0·000025		0·00		
Sept. 1	1 in 80	7·36	9·17	6·46	2·12	13·41	13·34	0·00056	0·00	0·0001	0·0008	Ditto.
	Differences, . .	+ 1·81		− 4·34		..	..	− 0·00056		+ 0·0007		

It may be remarked that nitrous acid was *not* detected in any of the solutions of this series of experiments.

* This volume includes N, CH_4, and H, disengaged during fermentation, but they were not separately determined.

† The remainder of this solution was, immediately after examination, re-aerated, analysed, and set aside to ferment till September 1st, when it was re-examined, with the following results :—

1893	..	11·31	11·99	5·78	1·44	12·96	12·99	0·00115	0·00	0·0001	0·0017	..
Sept. 1	Differences, . .	+ 0·68		− 4·34		..	..	− 0·00115		+ 0·0016		

Multiplying each set of differences as before, we get:—

TABLE IV.

Solution.	Multiplier.	1. CO_2	2. N as NH_3	3. N as N_2O_5	4. O in c.cs. $= N_2O_5$	5. Sum of 1 and 4.	6. Vol. of O_2 absorbed.
1/10 . .	10	+ 61	+ 0·002	0·0	0·0	61	64
1/20 . .	20	+ 111	+ 0·005	0·0	0·0	111	123
1/40 (1st stage)	40	+ 112	+ 0·001	0·0	0·0	112	132
1/40 (2nd stage)	40	+ 27	− 0·046	+ 0·064	204	231	174
1/80 . .	80	+ 145	− 0·045	+ 0·056	179	324	347

We see from the above Table that in solution 1/10 the dissolved oxygen was not in sufficient quantity for the first stage of fermentation; hence putrefactive fermentation had occurred.

But in the two following solutions it was; and in each the volume of carbon dioxide formed and the volume of oxygen absorbed were directly proportional to the quantity of fermentable matter originally present therein.

We further note that the time allowed for fermentation, 1/20 and 1/40, was only sufficient for the carbon fermentation, and that in neither had nitrogen fermentation commenced. We may therefore note this result, as in this experimentfully aërobic conditions were maintained throughout, and yet no nitrification occurred; we may consider it as strong evidence in favour of the view that the fermentative changes really occur in two distinct stages—a view which other observers have maintained, and which I have assumed as true in the earlier part of the Paper.

It is important to note that the oxidation of ammonia to nitric acid is accompanied in solution 1/40 and inferentially in 1/80, by the formation of relatively small quantities of carbon dioxide.

The gas so formed was probably derived, as I shall show by later experiments, from the small quantities of oxidized organic substance which, as we shall find later, may under certain conditions be formed from the sewage-matters during the first stage of fermentation. The collected results for solution 1/40, and those for 1/80, show that when both stages are complete the quantities of carbon dioxide and nitric acid formed, and the volume of oxygen absorbed, were practically directly proportional to the quantity of fermentable matter originally present.

Putting the results in a quantitative form as before, we may say that 1000 volumes of sewage-water required 306 to 347 volumes of atmospheric oxygen for the complete fermentation, 125 to 132 volumes being required for the first stage, and 181 to 215 for the second stage.

The filtered sample of sewage from the Richmond Works, when similarly examined, gave the following results:—

SERIES III.—COMMENCED JUNE 24TH, 1893.

TABLE V.—*Experiments with Sewage-water, which has been filtered through gravel filter-beds, and tap-water.*

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_3 I.	N as N_2O_3 II.	N as N_2O_5 I.	N as N_2O_5 II.
1893													
July 18	1 in 2	77·50	83·85	6·38	0·00	13·58	13·70	0·0085	0·0075	0·0018	0·0016	0·003	0·0045
	Differences, .	+ 6·35		− 6·38		..	..	− 0·001		− 0·0002		+ 0·0015	
July 19	1 in 4	41·29	44·00	6·43	0·00	13·58	13·54	0·00425	0·0030	0·0009	0·00003	0·00155	0·0028
	Differences, .	+ 2·71		− 6·43		..	..	− 0·00125		− 0·00087		+ 0·00125	
July 20	1 in 8	23·18	24·80	6·45	0·00	13·58	13·43	0·00213	0·0005	0·00045	0·00	0·000825	0·0028
	Differences, .	+ 1·62		− 6·45		..	..	− 0·0016		− 0·00045		+ 0·00198	
July 24	1 in 16	14·12	15·11	6·46	3·41	13·58	13·54	0·00107	0·00025	0·000225	0·00	0·000402	0·0015
	Differences, .	+ 0·99		− 3·05		..	..	− 0·00082		− 0·000225		+ 0·001	

REMARK.—All the solutions were quite free from odour after fermentation.

On multiplying each set of differences, so as to make them comparable one to another, and to the undiluted sample, we get:—

TABLE VI.

Solution.	Multiplier.	1. CO_2	2.* N as N_2O_3 oxidised to N_2O_5	3. $O_2 = N_2O_3$ oxidised.	4.† N as N_2O_5 from NH_3	5. $O_2 = NH_3$ oxidized.	6. Sum of 1, 3, and 5.	7. Vol. of O_2 absorbed.
1/2	2	12·7	0·0004	0·32	0·0026	8·29	21·31	12·8
1/4	4	10·8	0·00348	2·78	0·0015	4·79	18·37	25·7
1/8	8	13·0	0·0036	2·86	0·0122	38·92	54·80	51·0
1/16	16	15·8	0·0036	2·88	0·0124	39·56	58·24	48·8

In the results given in these two Tables we have still further evidence that the volume of oxygen absorbed is practically proportional to the quantity of matters fermented; but in them we have also a more definite indication of the chemistry of at least one phase of nitrification than is observable in those of the two preceding series of experiments.

It may be taken for granted, I think, from the fact that nitrification had already been well established in this sample of filtered sewage-water before the commencement of my experiments, and from the general character of the results obtained, that the first stage of fermentation had been completed during the process of filtration to which it had been subjected at the Works from which it had been collected.

We have therefore in this series of experiments illustrations of the second stage of fermentation or true nitrification only; and it fortunately happens that the dilutions made up were just of sufficient strength to clearly illustrate the chemical changes which accompany nitric fermentation in polluted waters during their passage through land or artificial filters.

* The numbers in this column have been calculated on the assumption that N as N_2O_3, shown to have been lost during fermentation, was completely oxidized to N_2O_5; and the figures in the next column have been calculated on the assumption that the oxidation of the N_2O_3 took place according to the equation $N_2O_3 + O_2 = N_2O_5$.

This gives 0·8 c.cs. oxygen required to oxidize 0·001 grammes N as N_2O_3 to N_2O_5.

† The numbers in this column give the N_2O_5 less the loss of N_2O_3 during fermentation, and it is assumed that these quantities were derived from ammonia. The numbers in the next column have been calculated on this assumption, as already explained. These four columns have been added simply for the purpose of approximate comparison.

It will be observed that the total N as NH_3 and N_2O_3 lost in the case of each solution, except solution 1/4, is nearly equal in quantity to the N as N_2O_5 formed.

It will be observed, on looking over the results given in the two foregoing Tables, that a fermentation of both nitrous acid and ammonia into nitric acid took place in each solution; that the fermentation of the nitrous acid in solutions 1/2 and 1/4 was incomplete, but complete in the remaining solutions, and that the ammonia was not completely oxidized in any of the solutions; and finally, that a decided quantity of carbon dioxide was formed during fermentation in each solution. This last noted product becomes of interest, and I may say of importance, when considered in relation to the recent researches of Dr. Munro, Professor P. F. Frankland and Mrs. G. C. Frankland, Mr. Warrington, and M. Winogradsky, already referred to, on the nitrification of ammonia in the absence of organic matters. These observers have all shown that the product of fermentation of ammonia in the absence of organic matter is invariably nitrous acid; and Winogradsky has supplied quantitative proof that the nitrous organism produces organic matters from inorganic materials, about thirty-five parts of nitrogen being oxidized for one part of carbon assimilated from ammonium carbonate. In the above tables we see that the nitric fermentation therein illustrated is accompanied by the formation of very distinct volumes of carbon dioxide, just as was noted in reference to the second experiment recorded in Table III. The question arises, what was the nature of the organic matter from which this gas was derived.

From the next series of experiments, which I shall have to describe, we shall find evidence which goes to show that the organic matters which undergo change during a second stage fermentation of the character above illustrated, have themselves been formed during a first stage fermentation under aërobic conditions.

The results recorded in Table V. for solution 1/4 require special reference, as they appear to be exceptional when compared with those afforded by the other solutions of the series.

Thus, relatively less carbon dioxide was formed in it; and the total inorganic nitrogen found after fermentation was decidedly less than that present before fermentation, the quantities being 0.00583 and 0.00670 parts per 1000 respectively. On the other hand, the volume of dissolved oxygen actually absorbed was relatively similar to that absorbed in the other solutions.

The exceptional results here apparent are not, I consider, due to experimental errors; they are rather to be ascribed to a difference of type, or phase, of a second stage fermentation.

In the other solutions of this series we have apparently one and the same type of nitrogen fermentation taking place, viz. a fermentation of NH_3 and N_2O_3 into N_2O_5, accompanied by a fermentation of organic matter. In the solution under discussion we have also this type of fermentation occurring, but, apparently, in addition, another type, viz. the oxidation of ammonia, and possibly also of

nitrous acid to nitric acid, accompanied by a fixation of small quantities of inorganic materials, presumably to form organic matter, as Winogradsky has shown takes place in the nitrous fermentation of ammonia in the absence of organic matter.

That a number of variations are possible during the fermentation of NH_3 and N_2O_3 in the presence of organic matters that have undergone the first stage of fermentation, I shall show by further experiments.

Regarding the method of examination, illustrated by these experiments, simply as an analytical probe, it is quite evident that it affords the means of differentiating the character of fermentable matters in waters, and approximately estimating their amount, to a degree quite beyond the power of any other method. Thus, when the samples of raw and filtered sewage water were examined by the methods commonly used, the following results were obtained:—

Constituents expressed as parts per 1000.

	Untreated Sewage-Water.	Filtered Sewage-Water.
Free Ammonia, ...	0·0475	0·017
Albuminoid Ammonia, ...	0·005	0·0012
Oxygen absorbed from standard $KMnO_4$ acting in the cold for three hours, ...	50·2 c.cs.	16·2 c.cs.

It is impossible, of course, to draw any conclusion as to the character of the organic matters in either sample from the above results. They do not even give any definite idea of the actual quantities of the organic matter in the samples, neither do they afford the means of estimating the influence which such liquids would exert in river-water when discharged into it. While, on the other hand, the results afforded by the experiments of Series II. and III., above described, give complete answers to each of these points. They show that, on the one hand, the untreated sewage-water underwent a first stage fermentation before true nitrification, and therefore contained matters which would set up putrefaction if the supply of atmospheric oxygen to all parts were restricted, and that, on the other hand, the filtered sewage-water did not, but nitrification alone, and that therefore putrefaction was impossible in the liquid, even when the supply of dissolved oxygen was restricted. They further show the exact volumes of atmospheric oxygen required for the complete fermentations in the untreated water, and that required for the complete fermentation in the filtered water, giving at the same time the quantities and character of the products of fermentation.

The next series of experiments which I have to describe were made with solutions of definite chemical compounds, and it will, I think, be also of advantage to discuss them, not in their chronological order, but in such a way as may best serve to bring out the points I am anxious to establish in this research.

I will therefore first describe a series of experiments carried on with a solution of asparagine and crystallized potassium sodium tartrate. A strong solution was made up, containing 0·066, and 0·141 grammes of these bodies, respectively; also 0·1 gramme of potassium phosphate per litre of solution; only two dilutions were made from this, it being determined to commence the experiments with a considerable quantity of each solution in several bottles, and if necessary, after determining the products of a fermentation, to re-aërate and analyse, and to put up again in smaller bottles for a further fermentation. It was hoped by this means to gain, more especially, definite information on the question whether ammonia was formed during the first stage fermentation of a nitrogenous substance, in the continued presence of an excess of dissolved oxygen or not.

There were other reasons for making this modification in detail of the method of examination, which will appear as the results of the experiments are considered.

The full particulars of these experiments are given in the subjoined Tables VII. and VIII.

[TABLES VII. AND VIII.

Series IV.—Commenced March 6, 1894.

Table VII.—*Experiments with Asparagine and Sodium Potassium Tartrate.*

Solution A contained 0·066 grams asparagine,
0·141 ,, sodium potassium tartrate, cryst., } per litre.
0·1 ,, potassium phosphate.

No. of experiment.	Date of commencement and of conclusion of experiment.	Nature of Experiment.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5	Remarks.
1	March 6, 1894,	Solution A, as above (in tap-water), . .	11·21	7·86	15·93	0·0	0·0	0·0001	
	,, 12, ,,	Same after fermentation, ...	26·73	0·05	16·13	0·0093?	0·0	0·0	Liquid very turbid, but free from odour.
		Differences, ...	+15·52	−7·81	—	+0·0093?	—	—	
2	,, 12, ,,	Remainder of preceding solution, after fermentation, re-aerated, = A′, . .	26·62	7·36	15·14	0·0095?	0·0	0·0	
	,, 13, ,,	A′ after fermentation, ... I.	37·16	1·52	15·30	0·0108?	0·0	0·0	Ditto.
	,, 14, ,,	Another bottle of A′ after fermentation from March 12, ... II.	40·15	0·05	15·16	0·0102?	0·0	0·0	Ditto.
		Differences, ... I.	+10·54	−5·84	—	+0·0013?	—	—	
		Differences, ... II.	+13·53	−7·31	—	+0·0007?	—	—	
3	,, 14, ,,	Remainder of solution A′ (March 14) diluted with equal volume of distilled water and aerated = A′/2, ...	20·62	7·81	16·11	0·0032	0·0	0·0	
	,, 19, ,,	Same after fermentation, . . . I.	32·21	1·72	15·92	0·0045	0·0	0·0	Faint sour odour; turbid.
	,, 19, ,,	Another bottle of A′/2 after fermentation, II.	32·01	1·56	15·89	0·0038	0·0	0·0	Ditto.
		Differences, ... I.	+11·59	−6·09	—	+0·0013	—	—	
		Differences, ... II.	+11·39	−6·25	—	+0·0006	—	—	
4	,, 19, ,,	Remainder of liquid from two preceding analyses, mixed and aerated, . .	29·06	7·56	15·60	0·0030	0·0	0·0	
	April 12, ,,	Same after fermentation, ...	36·75	0·00	15·40	0·0056	0·0	0.0	No distinct odour.
		Differences, ...	+ 7·69	−7·56	—	+0·0026	—	—	
5	,, 12, ,,	Remainder of preceding solution re-aerated,	31·42	7·04	13·98	0·004	0·0	0·0	
	August 1, ,,	Same after fermentation, . . .	35·22	0·0	14·10	0·0044	0·0015	0·0	Quite free from odour.
		Differences, ...	+ 3·80	−7·04	—	+0·0004	+0·0015	—	
6	,, 1, ,,	Remainder of preceding solution diluted with an equal bulk of distilled water and aerated, ...	17·033	6·11	12·67	0·0022	0·0009	0·0	
	Jan. 4, 1895,	Same after fermentation, . . . I.	16·69	0·07	12·55	0·0	trace	0·002	
	,, 14, ,,	Another bottle of same after fermentation, II.	16·79	0·05	12·63	0‘0	0·00016	0·00204	
		Differences, ... I.	− 0·34	−5·94	—	−0·0022	−0·0009	+0·002	
		Differences, ... II.	− 0·24	−5·96	—	−0·0022	−0·00074	+0·00204	

Series IV.—*continued.*

Table VIII.—*Experiments with solution A diluted with tap water.*

No. of experiment.	Date of commencement and of conclusion of experiment.	Nature of Experiment.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5	Remarks.
1 *a*	March 6, 1894,	Solution A from Table VII., diluted with tap-water in the proportion of 1 : 9 vols.,	4·65	7·86	15·93	0·0	0·0	0·0001	
	,, 15, ,,	Same after fermentation, ...	9·32	4·52	15·75	0·0008	0·0	0·0001	Slightly turbid, no odour.
		Differences, ...	+ 4·67	- 3·34	—	+ 0·0008	—	—	
2 *a*	,, 15, ,,	Remainder of preceding solution aerated, .	9·05	7·35	15·64	0·0008	0·0	0·0001	
		Same after fermentation, ...	12·28	2·06	15·47	0·0	0·0	0·0015	
	May 17, ,,	Differences, ...	+ 3·03	- 5·19	—	- 0·0008	—	+ 0·0014	
3 *a*	March 6, ,,	Solution A from Table VII., diluted with tap-water in the proportion of 1 : 19 vols., I.	4·29	7·86	15·93	0·0	0·0	0·0001	
	,, 20, ,,	Same after fermentation, . . . II.	6·86	5·63	15·94	0·0008	0·0	0·0001	
		Differences, ...	+ 2·57	- 2·23	—	+ 0·0008	—	—	
4 *a*	,, 20, ,,	Remainder of preceding solution immediately transferred to a smaller bottle, and							
	April 30, ,,	after further fermentation again analysed,	8·04	4·02	15·86	trace	0·00048	0·00042	
		Differences (from II.), . . .	+ 1·18	- 1·63	—	- 0·0008	+ 0·00048	+ 0·00032	

Continuing the train of thought suggested by the three preceding series of experiments, we may note in the first instance that the experiments recorded in the Tables VII. and VIII. afford further evidence that the fermentation, which may take place in a natural water containing unfermented matters in solution, under aërobic conditions, does so in two distinct stages.

That ammonia, and not nitrous or nitric acid, is formed during the first stage of fermentation of nitrogenous organic matters, even in the continued presence of an excess of dissolved oxygen, is clearly proved by experiments 1, 2, and 3, in Table VII., and by 1*a* and 3*a* in Table VIII.

We may note also that experiment 6, recorded in Table VII., affords another, but more definite, illustration of that phase of nitrification, which had apparently been set up in solution 1/4 of Series III., and which, as I stated above, might afford an explanation of the exceptional results afforded by this solution. From the results recorded of this experiment 6, we see that an oxidation of ammonia, and possibly also of nitrous acid, took place, and that at the same time small quantities of carbon dioxide, and also of ammonia, or of nitrous acid, or both, were fixed, no doubt, from Winogradsky's experiments, to form organic matter. It is interesting to observe that in each experiment here quoted, the quantity of nitric acid formed is practically exactly equivalent to that of ammonia lost, and that the difference between total inorganic nitrogen before and after fermentation corresponds with the loss of nitrous nitrogen during fermentation. It is just possible from this, that, in nitric fermentation, nitrous acid may enter into the reaction by which organic matters are formed from inorganic materials. But this requires further experimental investigation.

Another point to be noted in reference to these two experiments is, that in one (solution 1/4, Series III.) the volume of dissolved oxygen absorbed is decidedly in excess of that theoretically required for the oxidation of ammonia to nitric acid, while it is a little less in the other experiment (6). This difference may have been due to a difference in character of the organic matter present in the two solutions, since there can be no doubt, from experiments I have yet to describe, that organic matters which have themselves undergone change during a previous first stage fermentation, exercise a marked influence on the subsequent stage of fermentation, or true nitrification, and that these fermented organic matters vary very much in chemical character, so far as nitrification is concerned, I hope to illustrate by further experiments.

The quantities of carbon dioxide, and inorganic nitrogen fixed in experiment 6 are small, so small, in fact, that the errors attending their determination are unfortunately much too appreciable to warrant an attempt to draw definite conclusions as to any quantitative relationship which may exist between them.

The modification in the method of experimenting employed for the Series IV.,

renders it possible, it will be seen, to examine the intermediate steps of both the first and the second stage fermentations, and to obtain important results.

To confine attention, in the first instance, to the intermediate steps of the first-stage fermentation recorded in experiments 1, 2, 3, and 4, in Table VII., we notice that during the steps represented by the first three experiments much larger volumes of carbon dioxide were formed than could be accounted for on the assumption that the fermentation in each case consisted of a simple oxidation effected through the agency of the active organisms present in the solution, upon a quantity of the organic matters equivalent to the volume of dissolved oxygen absorbed. Thus, the calculated ratio of carbon dioxide formed to that of the oxygen absorbed by the complete oxidation of the asparagine to carbon dioxide, water, and ammonia, and of potassium sodium tartrate, to its ultimate products of oxidation, are, respectively, as 1·33 : 1, and 1·6 : 1, and if equivalent proportions of these two substances be oxidized at the same time, then the ratio becomes 1·465 : 1. On the other hand the ratios of the volumes of carbon dioxide actually formed to those of oxygen absorbed, in experiments 1, 2, and 3, are as 2 : 1, 1·85 : 1, and 1·86 : 1, respectively. While for experiment 4 this ratio drops nearly to 1 : 1.

It is quite evident, therefore, that, notwithstanding the fact that the earlier steps of the first stage fermentation represented by experiments 1, 2, and 3, were attended throughout with aërobic conditions, changes other than those which would result from simple oxidation by the dissolved oxygen absorbed, must have been set up in the organic matters present in the solution. These changes seem to have been complete by the end of the step represented by experiment 3, for the ratio of carbon dioxide formed to oxygen absorbed during the next stage represented by experiment 4, drops suddenly to 1 : 1.

This ratio is so low that we are justified in believing that the organic matters which underwent fermentation during this last step were not unfermented portions of the matters originally present, but were themselves the products of the changes which we have seen must have been set up during the earlier steps of fermentation represented by experiments 1, 2, and 3.

In experiment 5 it appears we have illustrated the completion of the first-stage fermentation, and the commencement of the second stage. Judging from the quantities of carbon dioxide, ammonia, and nitrous acid formed, and oxygen absorbed, it is probable that nearly the whole of the first-named product should be referred to the first stage. Thus the volume of oxygen theoretically required to oxidize 0·0015 grammes nitrogen as ammonia to nitrous acid equals 3·585 c.cs. Deducting this from the volume of oxygen shown by the experiment to have been absorbed, we get 3·455 c.cs., while the volume of carbon dioxide formed was 3·8 c.cs. These volumes approach sufficiently near in proportion to

those which are recorded for the preceding experiment 4, to allow us, I think, to regard them as indicating the volume of oxygen absorbed, and of carbon dioxide formed during the conclusion of the first-stage fermentation, without introducing serious errors.

If this assumption be allowed, we can sum together the volumes of carbon dioxide formed, and of oxygen absorbed, during each of the steps of the first-stage fermentation represented by experiments 1, 2, 3, 4, and 5, and obtain the total volume of carbon dioxide formed, and of oxygen absorbed, by the complete first-stage fermentation of the two organic substances originally present in solution A. Thus :—

—	CO_2	O_2
Experiment 1, ...	15·52	7·81
,, 2, ...	13·53	7·31
,, 3 (× 2), ...	22·98	12·34
,, 4 (× 2), ...	15·38	15·12
,, 5 (× 2), ...	7·6	6·91
Totals, . . .	75·01	49·49

The total volumes of carbon dioxide formed, and of oxygen absorbed, at the conclusion of the first-stage fermentation, we then see are 75·01 and 49·49 c.cs., respectively. The ratio of these numbers to one another is as 1·52 : 1, which approximates to the volumes of carbon dioxide and oxygen, which, as I stated above, would be respectively formed and absorbed, were the two substances present in solution A directly oxidised completely to the ultimate inorganic products, carbon dioxide, water, and ammonia, viz. 1·465 : 1.

It appears then, from this, that notwithstanding the fermentative changes which were set up in solution A other than those which would result from simple oxidation during the earlier steps of the first-stage fermentation, the total volume of carbon dioxide formed, and of oxygen absorbed, resulting from the complete first-stage fermentation of the two substances present in the solution, bear approximately the same proportion to one another as if the fermentation had consisted throughout of a simple and direct oxidation by the oxygen absorbed acting upon an equivalent quantity of the mixture of the two substances originally present in the solution.

On turning to the results of the experiments with the dilute solutions of A, recorded in Table VIII., we observe that dilution seems to exert a very decided

influence on the course, more especially of the earlier steps of the first stage fermentation.

Thus, from the first experiment with solution A diluted to 1 in 10, it is probable from the quantities of carbon dioxide and ammonia formed, that the first stage had run through but little more than half its course, but notwithstanding this, the ratio of carbon dioxide formed to oxygen absorbed is as 1·4 : 1.

The influence of dilution is still more markedly shown by the results recorded from experiment 3a with solution A diluted to 1 in 20. This experiment had been allowed a decidedly longer time for fermentation; and it seems probable from the quantity of ammonia formed, that the first stage had nearly run its complete course.

The ratio between the above two gases, respectively, formed and absorbed becomes as 1·15 : 1.

It seems then from these two experiments that in the fermentative changes that were set up in the earlier steps of the first-stage fermentation of these dilute solutions, the dissolved oxygen took part to a degree increasing with the dilution, and that the resulting compounds were in all probability more highly oxidized than those formed during similar stages of fermentation in the undiluted solution A.

On examining the results of the further experiment (4*a*) with the more dilute solution, recorded in Table VIII., we find evidence to show that the organic matters which are formed during the first stage in so dilute a solution, may themselves undergo further change during nitrification, and give rise to the formation of carbon dioxide coincidentally with the oxidation of ammonia.

But it is of importance to note that from the quantity of nitrous and nitric acids formed, and of oxygen absorbed, in experiment 4*a*, the formation of this carbon dioxide could not have been attended with the absorption of any but a relatively extremely small volume of oxygen.

On turning to the results obtained from the second experiment (2*a*), with the less dilute solution, we find evidence of a similar nature recorded.

It may be urged, and rightly so, that from the way in which the second experiment (4*a*) with the more dilute solution of A was carried out, the volume of oxygen absorbed during fermentation, recorded in Table VIII., is probably too low.

Unfortunately the quantity of liquid left from the experiment 3*a* was not sufficient to allow of re-aëration and analysis in the usual way before re-bottling; hence the necessity of carrying out experiment 4*a* in the manner described in the Table. During the operation of transferring the liquid to a smaller bottle, it, no doubt, absorbed a small quantity of oxygen from the air. This would not, of

course, be accounted for by the results recorded in the Table, and therefore the objection that the volume of oxygen given as absorbed during fermentation is probably too low.

I feel confident, however, from experiments which have, from time to time, been made in the course of my work, and which have given me the means of estimating the error attending the operation here described, with a liquid containing so much dissolved oxygen as this one did at the time of re-bottling, that the error certainly does not exceed 0·5 c.c.

It has already been pointed out, when discussing the results of the experiments with the filtered sewage-water, recorded in Table V., that the second-stage fermentation was accompanied by the formation of a decided quantity of carbon dioxide. It therefore appears from this that filtration affects the earlier steps of the first stage in much the same way that dilution does.

It is of importance to note in relation to the objects which I have had in view in the carrying out of this investigation, that, notwithstanding the variations in the chemical changes which these experiments with the solution of asparagine and tartrate have shown to be possible during the intermediate steps of fermentation, according as the quantities of fermentable organic matters and of atmospheric oxygen are varied, relatively to one another, the total quantities of carbon dioxide formed, and of oxygen absorbed, during the whole course of fermentation may, for practical purposes, be taken as independent of such variations, provided that aërobic conditions be maintained throughout the complete course of fermentation.

This will be readily seen when the products of the complete fermentation in each dilute solution are multiplied so as to render them comparable with those obtained from the undiluted solution A, thus :—

Solution.	Experiment.	CO_2	O_2 = to N_2O_3	O_2 = to N_2O_5	O_2 absorbed.
A/10	1*a* (× 10), ...	46·7	0·0	0·0	33·4
,,	2*a* (× 10), ...	30·3	0·0	44·66	51·9
	Totals, . .	77·0	0·0	44·66	85·3
A/20	3*a* (× 20), ...	51·4	0·0	0·0	44·6
,,	4*a* (× 20), ...	23·6	22·94	20·42	32·6
	Totals, . . .	75·0	22·94	20·42	77·2

We find from the above Table that the total volumes of carbon dioxide evolved during the whole course of fermentation in the dilute solutions, when multiplied

so as to render them comparable to the volume of the same gas evolved by the undilute solution A, are practically equal to one another, and also to the volume evolved during fermentation in the undiluted solution. They are respectively equal to 77, 75, and 75 c.cs.

With reference to the oxygen absorbed during fermentation, it will be seen that, in experiment 2*a*, the second stage was complete; and the total volume of oxygen absorbed during both the two stages, when multiplied by 10 for the purpose already explained, amounts to 85·3 c.cs.

In experiment 4*a* the oxidation of the nitrogen was not quite complete.

If, however, we add to the volume of oxygen given in the above Table, viz. 77·2 c.cs., the volume of oxygen theoretically required to oxidize the nitrous acid formed in this experiment to nitric acid, viz. 7·68 c.cs., we get a total volume 84·88 c.cs., which approximates to that given for the less dilute solution.

The experiments with solution A do not, unfortunately, give the means of estimating the oxygen absorbed during the second stage fermentation.

The carbon, both in the asparagine and tartrate employed in these experiments, was carefully determined by combustion in the ordinary way before commencing these experiments. The total organic nitrogen in solution A was also determined by Kjeldahl's method.

From these determinations it was found that the organic carbon per litre of solution was as follows:—

0·066 grammes asparagine	= 0·0225	grammes carbon,	}	equivalent to 85·37 c.cs. CO_2.
0·141 ,, tartrate	= 0·0234	,, ,,		
Organic nitrogen	= 0·0139	,,	per litre of solution.	

As already shown, the volume of carbon dioxide formed by the complete fermentation of these quantities of asparagine and tartrate may be taken as equal to 75 c.cs.

This volume approximates sufficiently close to 85·37 c.cs., the volume which would be formed by the complete oxidation of similar quantities of the same substances, to warrant us in regarding it for purposes of water analyses, as a quantitative expression of the amount of substances originally present in the water.

The solutions experimented with contained minute quantities of peaty colouring matters, besides the substances added. These matters, however, probably underwent little, if any, change.

I may here note that the volume of carbon dioxide formed by the fermentation of the peaty matters in the tap-water employed for making up the dilutions may be taken as about 1 c.c. per litre (see p. 561).

With reference to the quantities of ammonia, nitrous and nitric acids formed during fermentation, we observe that in experiment 3*a*, the quantity of nitrogen recorded as ammonia is approximately equal to that of the organic nitrogen originally present. The same may be said of the nitric nitrogen recorded in experiment 2*a*, and of the nitrous and nitric nitrogen recorded in experiment 4*a*. The ammonia determinations recorded in experiments 1 and 2 in Table VIII. are unreliable. They are probably much too high owing to the possibility, which was unfortunately recognised too late, that although the asparagine itself suffered no appreciable decomposition, when the original solution A was distilled in the presence of borax, the compounds formed from it by partial fermentation would, and thus give rise to an evolution of ammonia which did not exist as such in the original solution.

To avoid this possible source of error as much as possible, it was determined to nesslerize small portions of the solutions diluted with as large volumes of pure water as possible. The ammonia determinations recorded for all experiments after No. 2, both as regards the solution A itself, and with the diluted solutions made from it, were obtained by this means.

On summing up the results obtained from this series of experiments, we find they afford additional evidence in support of the conclusions which it was possible to draw from those afforded by the three preceding series of experiments with sewage waters, viz. that, when the dissolved oxygen is in excess relatively to the fermentable matter present in a water, the quantities of carbon dioxide and nitric acid formed, and of oxygen absorbed, *after complete fermentation*, may be taken as directly proportional to the quantities of the fermentable matters originally present in the water.

We have also evidence in these results which goes to show that the quantities of carbon dioxide and nitric acid formed on complete fermentation may be taken, for the purpose of water analysis, as quantitative expressions of the fermentable organic carbon, and of the total organic and inorganic nitrogen originally present in the water. This last conclusion is also supported by all the preceding series of experiments.

We see, however, from the results obtained from these solutions of known strength and composition, that the conditions of experimenting must be strictly laid down, and adhered to if definite conclusions are to be drawn, because :—

1. We learn that the volume of carbon dioxide evolved during a first stage fermentation, relatively to a given volume of oxygen absorbed, may vary, even under continued aërobic conditions, with the relative quantities of fermentable organic matters, and the dissolved oxygen originally present in the water.

When the first stage of fermentation is carried on under conditions such as obtained in the experiments with solution A, viz. the presence of a considerable excess of fermentable organic matters, relatively to the oxygen present, during the earlier steps of the fermentation, we find that the organic carbon present in the solution may be almost completely oxidized to carbon dioxide during the said first stage fermentation, and that little or none of this gas is formed during the after-fermentation of the ammonia in the same solution.

When, on the other hand, the conditions at the commencement are reversed, viz. the oxygen is large relatively to the fermentable matters present, we see from the experiments with the dilutions of solution A, and from those with the filtered sewage-water used in Series III., that the oxidation of the organic carbon to carbon dioxide during the first stage may be far from complete before the commencement of the second stage of fermentation, but that the organic matters undergo, partially at least, an intermediate stage of oxidation, and that the oxidized matters which result suffer further change during nitrification, and give rise to the formation of decided volumes of carbon dioxide.

2. We also learn that, under the same conditions, not clearly defined by the experiments in question (solution 1/4, Series III., and exp. 6, Series IV.), carbon dioxide and ammonia, and possibly also nitrous acid, may become fixed, even in the presence of organic matters (fermented) presumably to form organic matter.

At the same time we are warranted in believing, from the results hitherto considered, that when a number of dilutions of a water under examination are experimented with, as was done with the samples of sewage-waters above examined, a series of results are obtained which reveal at once an exceptional course of fermentation, such as that shown by solution 1/4 in Series III., and from which definite and valuable conclusions may be drawn as to the character of the organic matters present.

The experiments I have next to quote were made with a view more particularly of gaining further evidence in addition to that already given, as to the relationship between the quantity of inorganic nitrogen formed by the fermentation of sewage-waters under continued aërobic conditions, and that of the total organic nitrogen originally present. These experiments were made with three samples of partially purified sewage, from the same sewage-works. Each sample was filtered to separate matters in suspension, and diluted with tap-water in the proportion of 1 to 49, respectively. The dilutions were marked for reference, S_1, S_2, and S_3.

The total organic and ammoniacal nitrogen in each dilution was determined at the time of bottling, by Kjeldahl's method, and the ammoniacal nitrogen by direct nesslerization.

The following results were recorded :—

S_1 . . . Organic nitrogen per 1000 c.cs. of solution = 0·0016 grammes.
S_2 . . . ,, ,, ,, ,, ,, = 0·0020 ,,
S_3 . . . ,, ,, ,, ,, ,, = 0·0006 ,,

The particulars of the experiments are recorded in the subjoined Table :—

TABLE IX.

Solution.	Date.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5
S_1 . .	Nov. 16, 1894, .	5·89	6·77	16·64	0·0012	0·0	0·0002
,, . .	Jan. 16, 1895, .	10·48	3·62	15·50	0·0023	trace.	0·0002
	Differences, .	+ 4·59	− 3·15	− 1·14	+ 0·0011	—	0·0
S_2 . .	Nov. 16, 1894, .	7·85	7·35	16·10	0·0036	0·0	0·0002
,, . .	Jan. 21, 1895, .	15·18	0·15	15·16	0·0046	0·00112	0·0004
	Differences, .	+ 7·33	− 7·23	− 0·94	+ 0·001	+ 0·00112	+ 0·0002
S_3 . .	Nov. 17, 1894, .	7·13	7·44	16·06	0·001	0·0	0·0004
,, . .	Jan. 24, 1895, .	8·63	2·46	15·18	0·0001	0·0	0·0018
	Differences, .	+ 1·50	− 4·98	− 0·88	− 0·0009	—	+ 0·0014
Tap-water	Nov. 17, 1894, .	5·01	7·80	15·96	0·0	0·0	0·0002
,, I.	Jan. 23, 1895, .	5·11	7·72	16·01	0·0	0·0	0.0002
,, II.	March 4, 1895, .	5·20	7·60	16·03	0·0	0·0	00.002

So far as the relationships between the quantity of organic nitrogen originally present in a water, and that of the inorganic nitrogen which finally results from its complete fermentation are concerned, the above results do not do more than afford additional evidence of the general conclusions which those of the preceding experiments have yielded, viz. that much the greater portion of the fermentable organic nitrogen in a water, is converted into inorganic nitrogenous bodies. It is impossible, it is to be feared, to obtain more accurate results, with the present known method for the nitrogen determinations, whereby any more definite inference as to this relationship can be drawn than the general one just given, since the errors attending the various determinations required become very much too appreciable.

Notwithstanding, however, this want of precision in the nitrogen determination, the experimental details quoted in the above Table IX., when considered

together afford most valuable information, as to the character and quantity of fermentable matters present originally in the respective solutions experimented with.

Thus, for each solution we have a loss of oxygen determined with great accuracy. That recorded for the solution S_3 gives the volume of this gas required for complete fermentation, while the loss recorded for each of the other two solutions is seen to cover only a partial fermentation of the matters present. The volume of oxygen required for the complete fermentation of these two solutions could have been determined by additional experiments; and with the data which would have been thus obtained, we could have contrasted the three solutions as to the total volume of oxygen required for complete fermentation, or, what is of much greater importance, as we have seen already, in the analysis of water polluted with such matters as sewage, we could have distinguished the volumes of oxygen required for each of the two stages of fermentation in each.

Fixation of Atmospheric Nitrogen.

There are other results which these experimental solutions have furnished, to which the greatest interest will be attached, viz. those afforded by the atmospheric nitrogen determinations. These show that very distinct quantities of that gas were absorbed during fermentation in each solution, and they are, so far as I know, the first recorded observations showing directly that atmospheric nitrogen may be absorbed during bacterial fermentation.*

On reference to the Table IX. it will be seen that the loss of nitrogen was 1·14, 0·94, and 0·88 c.cs., for the three solutions respectively. These numbers are much too high to ascribe to experimental errors, and in proof of this I have appended to the results obtained with the experimental solutions those afforded by samples of the tap-water employed for making the dilutions, which were bottled and kept under exactly similar conditions.

In reference to these experiments with the tap-water, I may note that they afford additional evidence to that already given, that the minute quantity of peaty matters contained therein really undergo slow fermentation to a degree, which begins to be indicated by the method of observation which I have employed in these experiments, after about four months' keeping.

* Since the above was written, M. Winogradsky has published a paper describing the isolation and properties of a butyric ferment, which has the power of fixing free nitrogen.—Arch. Sciences Biol. 1895, 3, 297–352; also Chem. Soc. Jour. Abstr. 68, 283.

Fixation of Carbon Dioxide and of Ammoniacal Nitrogen.

There is yet one further point of interest which I have to mention in reference to these solutions, namely, an additional experiment which I made with the portion of the solution S_2, which remained after the various analyses had been made on the day recorded, viz. January 21st. It will be seen on reference to Table IX. that the solution on that date was very similar in composition, so far as the probable character of the organic matters, and also so far as the composition of the inorganic nitrogenous bodies it contained, was concerned; to those in which we have already observed a fixation of carbon dioxide and inorganic nitrogen to have occurred during fermentation, viz. in solution 1/4 and in experiment 6, recorded in Tables V. and VII. respectively. In order to ascertain whether a similar action would take place during a further fermentation of solution S_2, the remainder mentioned above was re-aërated and bottled, and analysed before and after keeping, with the following results:—

Date.	CO_2.	O_2.	N_2.	N as NH_3.	N as N_2O_3.	N as N_2O_5.
January 25, 1895, . .	10·67	7·6	15·22	0·0045	0·00128	0·0006
March 1, 1895, . .	9·90	0·0	15·25	0·0027	0·00128	0·00182
Differences, . .	− 0·76	− 7·7	—	− 0·0018	—	+ 0·00122

From the results just given, it will be seen that a fixation of carbon dioxide and ammoniacal nitrogen really occurred, as was anticipated during further fermentation, but that apparently the nitrous nitrogen, unlike that in the case of the two solutions above referred to, did not take part.

Before passing on to describe my experiments with waters containing considerable quantities of peaty matter, I will give some further experimental results, which will be found to support the general conclusions which have been drawn from those already considered.

The full details of the experiments are recorded in the subjoined Tables:—

SERIES V.—COMMENCED 27TH JUNE, 1894.

TABLE X.—*Experiments with Diluted Sewage-Water.*

No. of Experiment.	Date of Commencement, and of Conclusion of Experiment.	Nature of Experiment.	CO_2.	O_2.	N_2.	N as NH_3.	N as N_2O_3.	N as N_2O_5.	REMARKS.
1	June 27, 1894	1 volume of sewage-water, diluted with 2 volumes of distilled water, and aerated,	76·80	4·50	13·85	0·02	0·0	0·0	Odour slightly offensive.
	Aug. 30, ,,	Same, after fermentation, . . .	104·96	0·00	13·68	0·022	0·0	0·0	Very offensive odour of putrefaction and SH_2.
		Differences, . . .	+ 28·16	− 4·50	..	+ 0·002	..	..	
2	Aug. 30, ,,	1 volume of remainder of preceding solution, after fermentation, diluted with 2 volumes of distilled water, and aerated,	33·79	5·37	14·42	0·008	0·0	0·0	Distinct odour of SH_2.
	Nov. 21, ,,	Same, after fermentation, . . .	38·62	0·0	14·22	0·012	0·0	0·0	Offensive odour of putrefaction and SH_2.
		Differences, . . .	+ 4·83	*− 5·37	..	+ 0·004	..	..	
3	Nov. 21, ,,	Remainder of preceding solution, diluted with three times its volume of distilled water,	8·94	7·39	15·17	0·003	0·0	0·0	
	Jan. 12, 1895	Same, after fermentation, . . .	9·54	1·34	15·02	0·0	0·0	0·0015	Quite free from odour.
		Differences, . . .	+ 0·60	− 6·05	..	− 0·003	..	+0·0015	

* This volume of oxygen was probably not all consumed by the fermentative process. SH_2 and other reduced products of putrefactive fermentation were present at the commencement of the experiment, and a portion of the oxygen was, no doubt, taken up by the direct oxidation thereof.

SERIES VI.—COMMENCED 30TH DECEMBER, 1892.

TABLE XI.—*Experiments with Potassium Sodium Tartrate.*

Solution IV. contained 0·1 grammes carbon as potassium sodium tartrate (cryst),
0·1 ,, sodium carbonate,
0·1 ,, potassium phosphate,
} per litre.

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_5 I.	N as N_2O_5 II.
Aug. 10, 1893	IV.	22·42	40·84	8·40	0·00	16·72	16·87	0·0	0·0001	0·0001	0·00
	Differences, . .	+ 18·42		− 8·40		..	..	+ 0·0001		− 0·0001	
April 4, 1894	IV./5	7·49	32·55	8·40	0·00	16·72	16·47	0·0	0·0005	0·0001	0·00
	Differences, . .	+ 25·06		− 8·40		..	..	+ 0·0005		− 0·0001	
April 4, ,,	IV./10	5·62	23·17	8·40	0·00	16·72	16·48	0·0	0·0004	0·0001	0·00
	Differences, . .	+ 17·55		− 8·40		..	..	+ 0·0004		− 0·0001	
Dec. 21, ,,	IV./40 . .	4·23	9·45	8·40	1·94	16·72	16·25	0·0	0·0	0·0001	0·0006
	Differences, . .	+ 5·23		− 6·46		..	..	..	..	+ 0·0005	
Dec. 21, ,,	IV./80	3·99	7·84	8·40	5·49	16·72	16·47	0·0	0·0	0·0001	0·0006
	Differences, . .	+ 3·85		− 2·91		..	..	..	..	+ 0·0005	

REMARKS.—The ammonia formed during fermentation in dilutions IV./5 and IV./10 was derived, no doubt, from the nitrate, and possibly also, in the case of the latter dilution, from the peat in the tap-water.

Owing to the length of time (just two years) the dilutions IV./40 and IV./80 were kept, there can be little doubt, since an excess of oxygen was present in each, that the peaty matter in the tap-water employed for their preparation underwent fermentation as well as the tartrate. This will account for the nitrates formed in these solutions, and also for the relatively large volumes of carbon dioxide found therein, compared with the less dilute relations. (See Table XIV.)

The considerable differences shown by the atmospheric nitrogen determinations in the case of the dilute solutions, may be, partially, at least, due to fixation, but this may also be due to greater errors than those commonly arising, owing to the very long time the solutions were kept.

SERIES VII.—COMMENCED 30TH DECEMBER, 1892.

TABLE XII.—*Experiments with Potassium Sodium, Tartrate, and Ammonium Chloride.*

Solution B contained 0·0468 grammes carbon as potassium sodium tartrate (cryst.),
0·01 ,, nitrogen as ammonium chloride,
0·10 ,, sodium carbonate,
0·10 ,, potassium phosphate,
} per litre.

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_5 I.	N as N_2O_5 II.	N as N_2O_3 I.	N as N_2O_3 II.
1893 May 5	B	21·45	44·16	8·45	0·0	16·81	16·68	0·01	0·0095	0·0001	0·00	0·00	0·00
	Differences, .	+ 22·71		− 8·45		..	..	..	..	..	..	..	..
,, 8	B/5	7·30	21·99	8·46	0·0	16·81	16·78	0·002	0·001	0·0001	0·00	0·00	0·00
	Differences, .	+ 14·69		− 8·46		..	..	− 0·001		− 0·0001		..	..
,, 10	B/10	5·53	13·59	8·46	0·07	16·81	16·62	0·001	0·00005	0·0001	0·0004	0·00	0·0006
	Differences, .	+ 8·06		− 7·76		..	..	− 0·00095		+ 0·0003		+ 0·0006	
,, 10	B/15	4·94	10·49	8·46	3·39	16·81	16·63	0·00067	0·00	0·0001	0·00047	0·00	0·00048
	Differences, .	+ 5·55		− 5·07		..	..	− 0·00067		+ 0·00037		+ 0·00048	
,, 15	B/20	4·64	8·63	8·46	4·35	16·81	16·62	0·0005	0·00	0·0001	0·0008	0·00	trace
	Differences, .	+ 3·99		− 4·11		..	..	− 0·0005		+ 0·0007		+ trace	
,, 16	B/40	4·20	6·23	8·46	6·16	16·81	16·60	0·00025	0·00	0·0001	0·0005	0·00	0·00
	Differences, .	+ 2·03		− 2·10		..	..	− 0·00025		+ 0·0004		..	..

REMARKS.—It will be observed that solution B contained practically a similar quantity of organic carbon to solution A (Table VII.), and on comparing the volumes of carbon dioxide formed on complete fermentation of the tartrate in these solutions with those obtained from the tartrate and asparagine in solution A and its dilutions, they will be found approximately equal thereto. (See also p. 613, and Table XVII.)

SERIES VIII.—COMMENCED 27TH MARCH, 1893.

TABLE XIII.—*Experiments with White of Egg.*

Solution I. contained 0·15 grammes white of egg,
0·10 ,, potassium phosphate, } per litre.
0·10 ,, sodium carbonate, }

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_3 I.	N as N_2O_3 II.	N as N_2O_5 I.	N as N_2O_5 II.
1894 March 29	I.*	22·70	39·24**	7·80	0·00	15·68	15·64	0·00	0·0026	0·00	0·00	0·0001	0·00
	Differences,	+ 16·54		− 7·80		..	..	+ 0·0026		0·00		− 0·0001	
,, 30	I./5†	7·77	13·18	7·80	1·43	15·68	15·47	0·00	0·00	0·00	0·00	0·0001	0·0017
	Differences,	+ 5·41		− 6·37		..	..	0·00		0·00		+ 0·0016	
,, 30	I./10†	5·91	9·42	7·80	3·93	15·68	15·55	0·00	0·00	0·00	0·00	0·0001	0·0012
	Differences,	+ 3·51		− 3·87		..	..	0·00		0·00		+ 0·0011	
,, 30	I./20†	4·97	6·95	7·80	5·23	15·68	15·52	0·00	0·00	0·00	0·00	0·0001	0·001
	Differences,	+ 1·98		− 2·57		..	..	0·00		0·00		+ 0·0009	
May 2	Tap-water I.	4·04	4·94	7·80	6·63	15·60	15·50	0·00	0·00	0·00	0·00	0·0001	0·0008
	Differences,	+ 0·90		− 1·07		..	..	0·00		0·00		+ 0·0007	
,, 3	Tap-water II.	4·04	4·89	7·80	6·78	15·60	15·50	0·00	0·00	0·00	0·00	0·0001	0·0008
	Differences,	+ 0·85		− 1·02		..	..	0·00		0·00		+ 0·0007	

* Very offensive. † Quite free from odour.

** The remainder of this solution, immediately after analysis, was mixed with an equal bulk of distilled water. The mixture, after thorough aëration and analysis, was then put into the same bottle as that in which solution I. was kept and preserved in the usual way. After a lengthened period it was again examined, with the following results:—

1895 January 2	Differences,‡	20·55	23·09	7·30	0·73	15·60	15·84	0·0014	0·00	0·00	0·00032	0·00	0·0010
		+ 2·54		− 6·84		..	..	− 0·0014		+ 0·00032		+ 0·0010	

‡ After the conclusion of this experiment, a considerable quantity of a very thin transparent scale-like deposit was noticed on the sides of the bottle. See also notes to Table XI.

PART II.

Experiments with difficultly Fermentable Matters.

Colouring Matters of Peat.

As an example of difficultly fermentable organic matters, I have employed an extract of fresh peat, collected from a bog which was slightly submerged under running water, and which was situated on one of the Wicklow mountains, and far removed from any source of contamination with animal matters.

The sample of peat was collected on September 15th, 1893.

Two days after, an extract was prepared from it by boiling it in tap-water containing a little sodium hydrate. The extract was filtered into a large glass stoppered jar, which it filled to about two-thirds of its capacity. The extract was then of a deep brown, and it was allowed to ferment until March 8th in the following year, the stopper of the jar being taken off from time to time to renew the air. It was then thoroughly mixed with about five times its bulk of tap-water, and allowed to settle till the following day, when about six litres were decanted off, and the different experiments commenced, which are recorded in Tables XIV and XV.

The results of these experiments were looked forward to with very much interest for several reasons—

First, it was known that peaty-colouring matters in river-waters suffered but little oxidation or other change, unless the waters were subjected to the action of such bodies as clay, when the peaty matters were more or less completely separated by the precipitating action of the clay. There was good reason to believe, however, that the peaty matters in water, when fresh, do undergo at least a slight chemical change. This was evident from the analyses published in the "Sixth Report of the Rivers Pollution Commissioners."*

These show that the proportion of carbon to nitrogen in unoxidized peaty matter contained in upland surface water is as 11·9 : 1 ; but in peaty matter which has been exposed to oxidation in lakes or large reservoirs, the proportion became 5·9 : 1.

It was quite an open question, however, whether these matters undergo fermentation when present alone, or whether they exert any influence on the fermentation of fermentable matters when present together with such in a water.

* See also Dr. P. Frankland's Article on Water in "Thorpe's Dictionary of Applied Chemistry," vol. iii., p. 965.

Again, it will be observed that the proportion of carbon to nitrogen in peaty matters is very similar to that of the carbon and nitrogen found in the fermented matters which result from the complete fermentation of sewage during slow filtration through sand. We find from an experiment recorded by Dr. Frankland (Frankland's "Experimental Researches," p.751) that this proportion may be from 9·6 : 1 to 6·3 : 1.

The fermented organic matters which are formed during slow filtration of sewage through such substances as sand or pumice, besides showing a similarly high proportion of carbon to nitrogen, as peaty matter, and we may take it, a similar resistance to fermentation, since it must be remembered these matters are obtained in very decided quantities even after a fermentation in a filter, which has been so complete, that little more than traces of the original ammonia in the sewage may be left unfermented, also possess other properties such as colour and optical properties, which are very similar to those of peaty-colouring matters. Thus, on allowing sewage to percolate very slowly through a pumice filter, I have obtained effluent waters therefrom, coloured very decidedly with a brown tint, which could not be distinguished from the brown varieties of peaty matter, and which on analysis gave the proportion of carbon to nitrogen as 7·1 : 1.

Neither could it be distinguished from peaty water coloured to a similar depth of tint when examined by Professor W. N. Hartley's spectroscopic method. A similar series of dilutions of both afforded identical ultra violet absorption spectra.

The experiments with easily fermentable matters, which have already been quoted, more especially those with the effluent water from the sand filtration recorded in Table V., afford abundant evidence that the organic matters which are formed during the first stage fermentation of animal and vegetable substances may themselves take part in, and suffer a further oxidation during, the subsequent second stage.

The question naturally suggested itself—Do peaty matters undergo similar fermentative changes under similar conditions?

This question appeared the more interesting because from those of my experiments already recorded, and from others, I had come to the conclusion that the presence of small quantities of fermented organic matters, such as peaty-colouring matters, probably are essential to the *nitric* fermentation of *ammonia*, and that the failure to obtain a nitric fermentation of this body under conditions which, as the researches of Professor P. F. Frankland and Mrs. G. C. Frankland, of Warrington and of Winogradsky, have abundantly demonstrated, are most favourable to nitrous fermentation, may be ascribed to the complete absence of peaty or humus-like bodies.

In every experiment which I have made, and in which it has been found that

the oxidation of ammonia to nitric acid has been complete, small quantities of peaty or fermented organic matters have always been present. The same may be said, I think, of the experiments of the above observers in which nitric acid was formed.

In other experiments which I shall have to describe, and in which the only change in the conditions has been a practical absence of all organic matters, I have also obtained abundant nitrous fermentation, but no nitric. In reference to the experiments last mentioned, it is of importance and of interest to note that the organisms present were of the same mixed character as in the case of those experiments in which, as stated, I obtained nitric fermentation.

With these prefatory remarks, I may now proceed to the discussion of the experiments with the extract of peat above mentioned.

The details and results are recorded in the two following Tables :—

[TABLES XIV. AND XV.

SERIES IX.—COMMENCED 9TH MARCH, 1894.

TABLE XIV.—*Experiments with a Solution of Peat.*

Solution P contained 0·0033 grammes nitrogen as ammonia, ...
0·1336 ,, organic carbon, ... } per litre.
0·0079 ,, organic nitrogen, ...

No. of Experiment.	Date of commencement and of conclusion of Experiment.	Description of Experiment.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5
1	March 9, 1894,	Solution P, ...	114·65	7·14	14·27	0·0033	0·0	0·0
	May 11, ,,	Same after fermentation,*	136·03	0·0	14·70	0·0044	0·0	0·0
		Differences, ...	+21·38	−7·14	—	+0·0011	—	—
2	,, 18, ,,	Remainder of preceding solution diluted with twice its bulk of distilled water aerated and exposed to the air for a week, then aerated again and bottled = P/3†, ...	41·46	7·44	14·96	0·0012	0·0	0·0
	July 27, ,,	P/3 after fermentation, ...	48·96	0·0	15·08	0·00048	0·0	0·0004
		Differences, ...	+7·50	−7·44	—	−0·00072	—	+0·0004
3	July 27, ,,	Remainder of preceding solution aerated, .	44·91	6·45	12·86	0·00046	0·0	0·0004
	Nov. 15, ,,	Same after fermentation, ...	49·24	0·0	13·09	0·00014	0·0	0·0002
		Differences, ...	+4·33	−6·45	—	−0·00032	—	−0·0002
4	Nov. 16, ,,	Remainder of preceding solution aerated, .	48·06	7·24	14·86	0·00014	0·0	0·0002
	Jan. 29, 1895,	Same after fermentation, ...	50·96	2·75	14·67	0·0	0·0	0·0003
		Differences, ...	+2·90	−4·49	—	−0·00014	—	+0·0001
5	May 18, 1894,	A portion of the solution P/3 from experiment No. 2, diluted with twice its bulk of distilled water = P/9, ...	14·70	7·46	14·77	0·0004	0·0	0·0
	June 12, ,,	Same after fermentation, ... I.	16·67	3·95	14·67	0·0	0·0	0·00035
	July 20, ,,	Another bottle of same after fermentation, II.	19·02	1·77	14·74	trace	0·0	0·00035
	July 23, ,,	Another bottle, ... III.	19·21	1·66	14·69	0·0	0·0	0·00035
		Differences, ... I.	+1·97	−3·51	—	−0·0004	—	+0·00035
		,, ... II.	+4·32	−5·69	—	−0·0004	—	+0·00035
		,, ... III.	+4·51	−5·80	—	−0·0004	—	+0·00035
6	July 21, ,,	Remainder of solution II. aerated, . . .	17·75	6·42	13·22	trace	0·0	0·00035
	Nov. 22, ,,	Same after fermentation, ... IV.	19·15	3·91	13·27	0·0	0·0	0·0007
		Differences, ... IV.	+1·40	−2·51	—	—	—	+0·00035
	Jan. 30, 1895,	Another bottle of same after fermentation, V.	19·25	3·89	13·11	0·0	0·0	0·0007
		Differences, ... V.	+1·50	−2·53	—	0·0	0·0	+0·00035

* Very offensive odour.

† Free from offensive odour.

SERIES X.—COMMENCED 9TH MARCH, 1894.

TABLE XV.—*Experiments with Solution of Peat and Ammonium Chloride.*

Solution PA (= P/2 + AmCl.) contained 0·1 grammes ammonium chloride, . . } per litre.
0·069 ,, organic carbon, . . . }
0·004 ,, organic nitrogen, . . }

No. of Experiment.	Date of commencement and of conclusion of Experiment.	Description of Experiment.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5
1	March 9, 1894,	Solution PA = P/2 + Am Cl., . . .	59·29	7·4	15·14	0·1	0·0	0·0001
	May 12, ,,	Same after fermentation, ...	72·26	0·0	15·17	0·1	0·0	0·0
		Differences, ...	+ 12·97	− 7·4	—	—	—	− 0·0001
2	,, 14, ,,	Remainder of PA after fermentation diluted with twice its bulk of distilled water and aerated = PA/3, ...	23·80	7·26	14·54	0·032	0·0	0·0
	June 15, ,,	Same after fermentation, ...	25·55	0·0	14·55	0·028	0·00225	0·0
		Differences, ...	+ 2·75	− 7·26	—	− 0·004	+ 0·00225	—
3	,, 18, ,,	Remainder of PA/3 after fermentation aerated,	22·74	6·8	13·58	0·027	0·0024	0·0004
	,, 28, ,,	Same after fermentation, ...	22·18	0·0	13·60	0·023	0·0024	0·0037
		Differences, ...	− 0·56	− 6·8	—	− 0·004	—	+ 0·0033
4	,, 28, ,,	Remainder from preceding aerated, . . .	15·51	6·5	12·99	0·002	0·0021	0·004
	July 17, ,,	Same after fermentation, ...	16·58	0·15	13·09	0·0198	0·00048	0·0065
		Differences, ...	+ 1·07	− 6·35	—	− 0·0022	− 0·0016	+ 0·0025
5	,, 21, ,,	Remainder from preceding aerated, . . .	* 5·82	6·55	13·19	0·019	0·0006	0·0070
	Jan. 28, 1895,	Same after fermentation, ...	6·58	0·0	13·29	0·018	0·0032	0·0088
		Differences, ...	+ 0·77	− 6·55	—	− 0·001	+ 0·0026	+ 0·0018
1*a*	March 9, 1894,	Solution PA diluted with tap-water in the proportion of 1 to 9 = PA/10 = P/20 + AmCl., .	9·46	7·5	15·54	0·01	0·0	0·0001
	May 14, ,,	Same after fermentation, ...	21·52	0·0	15·55	0·007	0·0033	0·0
		Differences, ...	+ 12·06	− 7·5	—	− 0·003	+ 0·0033	—
2*a*	,, 16, ,,	Remainder of PA/10 aerated, ...	18·99	7·24	14·58	0·007	0·0033	0·0
	June 21, ,,	Same after fermentation, ...	19·96	0·0	14·48	0·0035	0·006	0·0004
		Differences, ...	+ 0·97	− 7·24	—	− 0·0035	+ 0·0027	+ 0·0004
3*a*	,, 22, ,,	Remainder from preceding aerated, . . .	14·83	7·2	14·15	0·0024	0·0009†	0·0067†
	Jan. 31, 1895,	Same after fermentation, ...	18·39	0·0	13·96	0·00005	0·004	0·00815
		Differences, ...	+ 3·56	− 7·2	—	− 0·00239	+ 0·0031	+ 0·00145
1*b*	March 9, 1894,	Solution PA diluted with tap-water in the proportion of 1 to 19 = PA/20 = P/40 + AmCl., .	6·69	7·5	15·54	0·005	0·0	0·0001
	May 15, ,,	Same after fermentation, ...	15·02	0·0	15·55	0·0026	0·0021	0·0004
		Differences, ...	+ 8·33	− 7·5	—	− 0·0024	+ 0·0021	+ 0·0003
2*b*	,, 17, ,,	Remainder of PA/20 aerated, ...	11·82	7·2	14·37	0·0018	0·0021	0·0004
	June 20, ,,	Same after fermentation, ...	11·06	0·0	14·28	0·0001	0·00018	0·00332
		Differences, ...	− 0·76	− 7·2	—	− 0·0017	− 0·00192	+ 0·00292

REMARKS.—* The very rapid reduction of carbonic acid, here shown during the time the liquid was exposed to the air, was confirmed by a duplicate analysis (5·81). The loss may have occurred by diffusion, but I have not observed so great a loss in any other of my experiments under similar conditions.

† These results show that an extremely rapid reduction of nitrous to nitric acid occurred when the liquid was exposed to the air between the 21st and 22nd June. The figures were confirmed by duplicate analyses.

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Referring to Table XIV. we find, from the first experiment, that the first stage fermentation of solution P was not complete at the time of commencing the experiments; the remaining portions of solution P were in consequence diluted, as described in the Table, with twice their bulk of distilled water, and exposed to the air for a week to allow of its completion.

From the fact that nitrification had commenced in experiment 2, we may take it that the first-stage fermentation in the solution had been completed. The points most markedly exhibited by experiments 2 and 3 are a formation of carbon dioxide and a loss of oxygen and ammonia. As for the indications of nitrification, they are decided in the former experiment; but the nitric acid formed was equivalent to only about half the quantity of ammonia absorbed, while in the latter experiment no nitric acid appears to have been formed, although a very decided quantity of ammonia was absorbed. It appears then from these experiments that a *fermentation of small quantities of ammonia in the presence of considerable quantities of peaty colouring matters may take place, in such a manner that the ammonia is absorbed, and carbon dioxide is formed, while oxygen is consumed in relatively considerable volumes, but that little or no nitric (no nitrous) acid may be produced.*

In experiment 4 the nitric acid formed is about equivalent to the ammonia absorbed. It is important, however, to note that this last product is the least marked result of the fermentation; the volume of carbon dioxide formed and oxygen consumed being relatively both very much larger in quantity.

Experiments 5 and 6 were made with a diluted portion of solution P/3 prepared for experiment 2, and the former of these two experiments was commenced on the same day as the last mentioned. It is possible and interesting, therefore, to compare the results obtained with the less and more dilute solutions P/3 and P/9.

The first result of fermentation shown with bottle I, on June 12th, less than a month afterwards, was the complete fixation of the ammonia, and the formation of a quantity of nitric acid practically equivalent to the ammonia lost, accompanied by the formation of carbon dioxide.

The results obtained on keeping the other portions of the same solution (in bottles II. and III.) for a further period of about six weeks, were, a further formation of a decided quantity of carbon dioxide and a consumption of oxygen, *but no additional formation of nitric acid.* On re-aërating, however, a portion of the solution in bottle II., remaining from the experiment, and keeping it in two bottles for further periods, one of four, and another of six months, we find a formation of carbon dioxide and a consumption of oxygen, accompanied by a formation of a decided quantity of nitric acid.

The carbon dioxide and nitric acid formed during this last fermentation must have been derived solely from the peaty matters present in the solution. They

therefore confirm the evidence which was afforded by the experiment with tap-water recorded in Tables IX. and XIII., to the effect that the minute quantities of peaty matter in the tap-water underwent a fermentation, though an extremely slow one, into carbon dioxide and nitric acid.

The influence of dilution on the fermentation illustrated by these experiments becomes more decidedly apparent when the oxygen consumed, and the products formed, during the different stages of fermentation represented by experiments 2, 3, and 4, with less dilute solutions, and by experiments 5 (bottle III.), and 6 (bottle V.) are respectively added together and compared. Thus :—

		O_2	CO_2	N as NH_3	N as N_2O_5
Solution P/3, . .	Exp. 2, 3, and 4, ...	− 18·38	+ 14·73	− 0·0012	+ 0·0003
Solution P/9, . .	Exp. 5 (III.) and 6 (V.), . .	− 8·33	+ 6·01	− 0·0004	+ 0·0007

In the less dilute solution P/3, it becomes evident from the above figures that during fermentation a considerable quantity of ammonia was absorbed, and that the quantity of nitric acid formed was, for the period during which the solution was under examination, only about one-fourth that of the ammonia originally present.

On the other hand, in the more dilute solution the reverse action appears to have taken place, since the quantity of nitric acid formed was nearly double that of the ammonia originally present.

Again, the volume of carbon dioxide formed in proportion to that of the oxygen consumed was larger, relatively, in the less than in the more dilute solution.

The fact that peaty matters, when mixed with ammonium chloride, readily undergo fermentation is more clearly demonstrated by the experiments recorded in the next Table XV.

These experiments, it will be noticed, were made with another portion of the same solution of peat, but with this difference, it was mixed with a relatively larger quantity of ammonium chloride. The results then obtained show that a variety of interchanges may occur between peaty matters and ammonia during fermentation.

Thus from experiment 2 we find 7·26 c.cs. oxygen, and 0·004 grammes of ammoniacal nitrogen were taken up, and only 0·00225 grammes of nitrous nitrogen were formed; the volume of oxygen theoretically equivalent to this quantity of nitrous nitrogen being 5·38 c.cs., a volume much less than that actually consumed. From experiment 3 we find the quantities of oxygen and ammoniacal nitrogen taken up are respectively 6·8 c.cs. and 0·004 grammes, and that of nitric nitrogen

formed, 0·0033 grammes; no carbon dioxide was formed during this stage of fermentation, but, on the contrary, 0·56 c.cs. were fixed.

The volume of oxygen theoretically equivalent to the nitric nitrogen formed, viz. 0·0033 grammes is 10·53 c.cs., a volume this time much in excess of that actually consumed. It would seem from the last observation that an interchange between the peaty matters and ammonia took place during this step of the fermentation, but no doubt of a different character, notwithstanding the fact that *carbon dioxide was fixed* rather than formed. It is perhaps right to mention that all the determinations given in this Table, and in the preceeding one, were made with extreme care, all being checked by duplicate analyses, and in the case of many of the nitrogen determinations by triplicate analyses, and further that some of the nitric nitrogen determinations were confirmed by Crum's method with Lunge's nitrometer.

Experiment 4 demonstrates another phase of interchange between the two bodies, and it must be noted of nitrous acid, during fermentation, thus the quantities of oxygen and ammoniacal and nitrous nitrogen taken up were, respectively, 6·35 c. cs., 0·0022 grammes, and 0·0016 grammes, and of carbon dioxide and nitric nitrogen formed, 1·07 cc. and 0·0025 grammes. The volume of oxygen theoretically equivalent to this last-mentioned quantity of nitric nitrogen, supposing part of it was derived from the 0·0016 grammes of nitrous nitrogen taken up and the rest from ammoniacal nitrogen, is 4·15 c.cs., a volume less again than that consumed.

In the last experiment with PA/3, we find a still further phase of interchange during fermentation demonstrated, the quantities of oxygen and ammoniacal nitrogen shown by this experiment as being taken up, and of nitrous and nitric nitrogen formed being, respectively, 6·55 c.cs., 0·001 grammes, 0·77 c.cs., 0·0026 grammes, and 0·0018 grammes. The total quantity of nitrous and nitric nitrogen formed was thus equal to 0·0044 grammes, a quantity largely in excess of the ammoniacal nitrogen taken up. The total volume of oxygen theoretically equivalent to the nitrous and nitric nitrogen formed, assuming that both were derived from the ammoniacal nitrogen, is 11·96 c.cs. There can, therefore, be little doubt from these results that the nitrous and nitric nitrogen formed during this last step of the fermentation, represented by experiment 5, were derived from compounds resulting from the interchanges which, we have seen, must have occurred between the peaty matters and ammonia present in the water during the earlier steps of the fermentation.

It must be remembered in reference to this point, that the organic nitrogen actually present in combination with the peaty matters in the solution PA/3 at the time these experiments were commenced was only 0·00133 grammes. If we sum together the quantities of ammoniacal nitrogen absorbed, and of the

products formed, we see clearly that, although as above shown, the peaty matters played an essential part in the changes which occurred during fermentation, but little carbon dioxide was formed, and that, so far as oxidized products are concerned, the fermentation was practically a nitrogen fermentation. The total figures are:—

O_2	CO_2	N as NH_3	N as N_2O_3	N as N_2O_5
− 26·96 c.cs.	+ 4·59 c.cs.	− 0·0112 grms.	+ 0·00645 grms.	+ 0·0076 grms.

The total nitrogen oxidized was, as will be seen from these figures, 0·01405 grammes, a quantity decidedly in excess of the ammoniacal nitrogen absorbed.

4·59 c.cs., of carbon dioxide is equivalent to 0·0025 grammes carbon, which is but a small fraction of the total quantity of the organic carbon originally present in solution PA/3, viz. 0·023 grammes.

We have seen that the reverse action to this took place in the solution P/3, which contained but little ammonia relatively to peaty matters. Thus the total volume of carbon dioxide formed was equal to 14·73 c.cs. This volume is equivalent to 0·008 grammes carbon. The oxidised nitrogen, it will be remembered, only amounted to 0·0003 grammes.

One further feature in connection with one of these experiments demands some notice. It is the very sudden diminution of carbon dioxide (shown by the first analysis in experiment 5) which occurred while the solution was kept in a stoppered bottle, only partially filled, from the 17th to the 21st July. No suitable explanation has occurred to my mind to account for this loss. No doubt a portion was due to diffusion into the air-space in the bottle, but with the records of the preceding experiments with the same solution, before one, it is difficult to conceive that the loss was wholly due to this cause. Another source of loss lies doubtless in the possibility of a portion of the gas being fixed by fermentation.

On turning to the experiments with PA/10, we find the influence of dilution shown as markedly as we have already seen it to be in the case of solution P/3 and of the more dilute solution P/9.

Experiment 1*a* shows that the nitrous nitrogen formed was practically equal to the ammoniacal nitrogen absorbed, but that the fermentative products differ essentially in one particular from those obtained simultaneously with nitrification with the less dilute solution, in that a considerable volume of carbon dioxide was formed. But notwithstanding this, the oxygen theoretically equivalent to the nitrous nitrogen = 7·85 c.cs., is slightly in excess of that consumed.

In experiment 2*a* the nitrous and nitric nitrogen together practically equalled the ammoniacal nitrogen lost, but this time, however, a very small volume of carbon dioxide was formed. The volume of oxygen theoretically equivalent to the nitrous and nitric nitrogen formed is 7·70 c.cs., a volume also slightly in excess of that actually consumed, viz. 7·24 c.cs.

It is interesting to note that the fermentation during these two experiments was practically a nitrous fermentation, but that when the solution remaining after the conclusion of the second experiment, was kept in a bottle only partially filled for a single day, the nitrous acid was almost completely fermented to nitric acid.

During fermentation in experiment 3*a*, the nitrous and nitric nitrogen formed, amounting to 0·00355 grammes, was considerably in excess of the ammoniacal nitrogen lost, and a decided quantity, viz. 3·56 c.cs., of carbon dioxide was produced. Nevertheless the oxygen theoretically equivalent to the total nitrous and nitric nitrogen, viz. 8·81 c.cs., is decidedly in excess of that actually consumed, 7·2 c.cs.

On summing together the differences from each experiment, it will be seen that, by the time of the conclusion of the experiment 3*a*, nearly all the fermentable matters, *i.e.* both peat and ammonia, originally present in solution PA/10, must have been fermented, thus:—

O_2	CO_2	N as NH_3	N as N_2O_3	N as N_2O_5
− 21·94 c.cs.	+ 16·59 c.cs.	− 0·00889 grms.	+ 0·0091 grms.	+ 0·00185 grms.

16·59 c.cs., CO_2 are equivalent to 0·00896 grms. The organic carbon originally present in the solution PA/10 was 0·0089 grms. The exact coincidence between these numbers is probably accidental. Again, the total nitrous and nitric nitrogen amounts, it will be observed, to 0·01095, while the total organic and inorganic nitrogen present in the solution when the experiments were commenced was 0·0107 grammes.

The volume of oxygen theoretically equivalent to the nitrous and nitric nitrogen, assuming that both were derived from the ammoniacal nitrogen, is equal to 27·66 c.cs., which is very much larger than that found by analysis to have been consumed. We may draw the conclusion, then, that the oxygen of the peat itself must have taken part in the fermentative changes.

It is of course, impossible to distinguish any very definite relationship between the figures just considered, owing to the fact that the errors attending them are too appreciable. I merely put them forward here to indicate, which we may

safely take it they do with a fair approximation to the truth, the extent and real nature of the changes which occurred during fermentation in the solution.

The results recorded for the more dilute solution PA/20, in the first experiment 1*b*, are similar in character to those just considered. The volume of carbon dioxide formed, viz. 8·33 c.cs. (equivalent to 0·0045 grammes carbon), shows that the peaty matters must have been nearly completely fermented, as the quantity of carbon present before fermentation was 0·0055 grammes.

It is interesting to note, further, in reference to the results from both the dilute solutions, that the earlier steps of the fermentation which they underwent were almost entirely nitrous.

The second experiment, 2*b*, with the more dilute solution, shows a fixation of carbon dioxide and of ammoniacal or nitrous nitrogen, or both. The oxygen theoretically equivalent to the nitric nitrogen, assuming that it was derived partly from the nitrous nitrogen lost, and the remainder from the ammoniacal nitrogen, is 4·73 c.cs., while the volume actually consumed was 7·2 c.cs.

General Conclusions from Experiments with Solutions of Peaty Matters and Ammonium Compounds.

On reviewing the evidence afforded by the experiments recorded in Tables XIV. and XV., we may draw the following general conclusions as to the various phases of fermentation which may occur in solutions of peaty matters and ammonium compounds, in the presence of the mixed organisms natural to water, under varying conditions of dilution and relative proportions:—

1. When the proportion of peaty matters present is large, such that the organic carbon amounts to 0·1336 grammes per 1000 c.cs., of solution, and that of ammonium compounds very small (such as 0·0079 grammes nitrogen as ammonia per 1000 c.cs.), a fermentation may occur in which the ammonia is taken up presumably to form new compounds with the peaty matters, since the nitric acid formed is relatively very small, and since also because very decided volumes of carbon dioxide are evolved.

The volume of oxygen consumed is decidedly in excess of that theoretically equivalent to the oxidised inorganic products formed during the fermentation.

2. When the same solution is decreased in strength by dilution, which is equivalent to increasing the proportion of oxygen, all other conditions remaining similar (except of course that of mass), the fermentation may take a different course; the volume of carbon dioxide formed becomes decided, and the ammonia becomes

entirely absorbed as before, but the oxidized inorganic nitrogen product is practically exactly equivalent to the ammonia absorbed.

The oxygen consumed is practically equal to that theoretically equivalent to the inorganic oxidized products formed.

3. Only nitric acid appears to be formed in the solutions under the stated conditions.

4. When the quantity of peaty matters is not large in proportion to that of the ammonium compounds present in the solution (organic carbon being equal to 0·069 grammes, and ammoniacal nitrogen to 0·1 grammes, per 1000 c.cs.), a fermentation may occur, during the earlier steps of which intermediate combinations between the peaty matters and the ammonia appear to take place, since during such stages the oxidized inorganic nitrogen compounds formed are not equivalent to the inorganic nitrogen taken up, while during a latter stage they are found to suddenly rise in quantity, and finally to become practically equivalent to it. Under these conditions the volume of carbon dioxide formed may be extremely small, relatively to that of oxygen consumed, or to the quantity of nitrogen oxidized.

The volume of oxygen consumed is, under these circumstances, very much less than that equivalent to the total oxidized inorganic products of the fermentation.

5. With the conditions stated under 4, we find that the nitrogen fermentation is both nitric and nitrous, the former predominating.

6. When the solution referred to under 4 is diluted, *i.e.* when the proportion of oxygen is increased, the other conditions remaining similar, the course of fermentation appears to be much modified. From the first a large volume of carbon dioxide is formed, and the oxidized inorganic nitrogen is practically equivalent to the ammonia absorbed. When further, the fermentation is pushed to completion, both peaty matters and ammonia appear to undergo nearly complete oxidation to inorganic products.

The volume of oxygen consumed is, under these conditions, also very much less than that equivalent to the total oxidized inorganic products of the fermentation.

7. It is interesting to note that the nitrogen fermentation in the dilute solution is both nitric and nitrous, the latter this time predominating, at least in the earlier stages of the fermentation.

For a further conclusion in reference to the subject, see p. 609.

Relationship between the Oxygen consumed and the Nitrous Acid formed during the Fermentation of Ammonia.

The experiments which have just been considered show that, when the fermentation of ammonia is carried on in the presence of peaty matters, the latter bodies take part in the fermentation, and prevent the true relationship between the oxygen consumed and the ammonia oxidized being seen. With the object of obtaining exact experimental data as to this point, I commenced a further series of experiments with a solution of ammonium chloride in distilled water, to which a little potassium phosphate and sodium carbonate were added, but no organic matter.

Some five litres of this solution were seeded with a few drops of the mixed sediments from the solution of peat (P/9), remaining in bottles II. and III. after the conclusion of experiment 5, recorded in Table XIV. I hoped by this solution to determine accurately the relation between the oxygen consumed and the nitrous acid formed, during a purely nitrous fermentation, carried on in the absence of peaty matters.

At the same time, in order to be able to compare the results of this experiment with those which would follow a fermentation by similar organisms in the presence of peaty matters, I started two further experiments with portions of the same peat solution remaining in the same bottles II. and III. To one portion I added a known quantity of ammonium chloride; to the other a known quantity of potassium nitrite. I had a further object in commencing these experiments, which I will describe later on.

The details and results of these experiments are given in the subjoined Table :—

[TABLE XVI.

TABLE XVI.—*Experiments to determine the relationship between the Oxygen consumed and Nitrous acid formed during the fermentation of Ammonia.*

No. of Experiment.	Date of commencement and of conclusion of Experiment.	Description of Experiment.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5
1	July 23, 1894,	Solution in distilled water containing a known quantity of ammonium chloride, and small quantities of potassium phosphate and sodium carbonate, but no added organic matter, seeded with a few drops of the mixed sediments from the solution of peat left in bottles II. and III. after the conclusion of experiment 5, recorded in Table XIV., .	32·96	6·48	12·94	0·0225	0·0	0·0
	Oct. 25, ,,	Same after fermentation, ...	32·72	0·0	12·91	0·020	0·00224	0·0
		Differences, ...	− 0·24	− 6·48	—	− 0·0025	+ 0·00224	—
1a	,, 26, ,,	Remainder of solution from preceding experiment, aerated, ...	31·52	7·13	14·03	0·019	0·00224	0·0
	Mar. 23, 1895,	Same after fermentation, . . bottle I.	31·25	0·04	13·87	0·016	0·00464	0·0
	,, 26, ,,	Ditto, ... ,, II.	31·40	0·06	13·95	0·016	0·00472	0·0
		Differences, ... I.	− 0·27	− 7·09	—	− 0·003	+ 0·00240	—
		,, ... II.	− 0·12	− 7·07	—	− 0·003	+ 0·00248	—
2	July 24, 1894,	1000 c.cs. of the mixed peat solutions remaining in bottles II. and III. from experiment 5, Table XIV, diluted with 2000 c.cs. distilled water containing a known quantity of ammonium chloride, ...	11·04	6·72	13·19	0·0045	0·0	0·0001
	Nov. 25, ,,	Same after fermentation, ...	10·92	0·0	13·38	0·0015	0·00016	0·00284
		Differences, ...	− 0·12	− 6·72	—	− 0·003	+ 0·00016	+ 0·00274
3	July 25, ,,	1000 c.cs. of the same peat solution mixed with 2000 c.cs. of distilled water containing a known quantity of potassium nitrite, .	11·05	6·72	13·19	0·0	0·0165	0·0025
	Nov. 30, ,,	Same after fermentation, ...	10·99	0·0	12·98	0·0	0·0016	0·0164
		Differences, ...	− 0·60	− 6·72	—	—	~ 0·0149	+ 0·0139

Experiments 1 and 1 *a* show that for the consumption of 6·48, 7·09, and 7·07 c.cs. of oxygen, 0·00224, 0·0024, and 0·00248 grammes of nitrous nitrogen were formed, respectively.

If we raise these volumes each to 10 c.cs., for convenience of comparison, then the quantities of nitrous nitrogen formed would be, respectively, 0·00344, 0·0033, and 0·00351. That is for 10 c.cs. (= 0·1437 grammes) of oxygen consumed, we have, taking the mean of these last three quantities, 0·00342 grammes of nitrous nitrogen formed. In other words, the formation of one part by weight of nitrous nitrogen is accompanied by the consumption of about 4·2 parts by weight of oxygen.

The volume of oxygen theoretically equivalent to the last-mentioned quantity of nitrous nitrogen, viz. 0·00342 grammes, on the assumption that it is derived from ammonia, is 8·14 c.cs.

Thus it will be seen, as was only to be anticipated, that, during the fermentation of ammonia in the absence of all organic matter, the volume of oxygen consumed is in excess of that theoretically equivalent to the nitrous acid formed, in the proportion of 10 : 8·14.

On turning to the result of the experiment with ammonium chloride and peaty matters, the influence of the latter on the former, during fermentation, is shown in a most marked manner. Thus, not only is the quantity of nitrous and nitric acids greater in the presence than in the absence of these substances, but the product of oxidation is almost entirely *nitric acid* and not nitrous acid, as in their absence; the oxygen consumed being much the same in both cases.

If we raise the volume of oxygen, viz. 6·72 to 10 c.cs., for convenience of comparison with the results from experiments 1 and 1 *a*, and the nitrous and nitric nitrogen in the same proportion, we find that for 10 c.cs. of oxygen consumed, 0·00024 grammes nitrous and 0·00408 grammes nitric nitrogen would be formed. These two weights are theoretically equivalent, on the assumption that they were both derived directly from ammonia, to 0·5036 and 13·02 c.cs. of oxygen, respectively.

We see from these figures that, when peaty matters are present with the ammonium compounds, the volume of oxygen consumed during fermentation, instead of being *larger*, is decidedly *less* than that equivalent to the ammoniacal nitrogen oxidized. These results then confirm those recorded in Table XV.

To consider now the determinations of the carbon dioxide. These show that, although the peaty matters must have so largely entered into the chemical changes set up during fermentation in this experiment, *no carbon dioxide was formed*, and it is extremely doubtful whether any was fixed, the difference recorded in the Table being possibly due to experimental errors.

It is possible also, since the ammoniacal nitrogen absorbed during the experiment was slightly in excess of the total nitrogen oxidized, that none of the latter was derived from the peat.

With reference to the question of the source of oxygen, the hydrogen of the ammonia may not have been so completely oxidized to water during the fermentation, in the presence of peaty matters, as in the absence of all organic matter. Some at least of the ammonical hydrogen may have been taken up by the peaty matters, and an increased quantity of oxidized nitrogen would, no doubt, be the results.

But whatever the mechanics of the chemical changes may be, which go on during fermentation, when peaty matters and ammonia are present together, the influence of those matters, one upon the other, cannot be doubted.

I have not hitherto referred to the loss of carbon dioxide shown by the experiments 1 and 1 *a* with the inorganic solution, because, in each case, it is so small as to be scarcely distinguishable from experimental errors. The determinations recorded are important, however, in showing that the carbon fixed must be very small compared with the nitrogen oxidized, and therefore they add additional evidence to that already given by Winogradsky, who showed, by a process of wet combustion, that the assimilation of 1 part of carbon was accompanied by the oxidation of about 35 parts of nitrogen as ammonia to nitrous acid. The mean of the losses of carbon dioxide shown by experiment 1 *a* is 0·15 c.cs., which is equivalent to 0·00008 grammes carbon, the ratio of the mean of the two quantities of nitrous nitrogen, recorded for the same experiment, viz. 0·00244 grammes, is as 1 : 30·5. These figures, it need hardly be said, are simply put forward here as confirmation of those given by Winogradsky.

In some of the preceding experiments, as I have before said, it appears that very definite volumes of carbon dioxide have been fixed, presumably during the formation of organic matters, but in all these experiments either peaty matters or fermented animal organic bodies, or, in the case of these latter, it should perhaps be said, both, as tap-water was employed for them, were present during fermentation.

Thus, the experiment with diluted sewage-water, S_2 recorded on page 588, shows a loss of as much as 0·77 c.cs., with a consumption of 7·6 c.cs. of oxygen, and the formation of only 0·00122 nitric nitrogen, and this experiment was carried out with extreme care, and it may be taken that the errors affecting the determinations are not seriously appreciable, since the quantities determined were small.

It appears then that peaty matters (*and also fermented animal matters*) *influence the quantity of carbon dioxide which may be fixed during a fermentation of ammonia.*

Referring now to the experiment (3) with potassium nitrite, it will be seen that as in the case of experiment (2) with ammonia and a portion of the same solution of peat, no carbon dioxide was either formed or fixed, so far as analysis could detect. The volume of oxygen theoretically required to oxidize the quantity of nitrous nitrogen which was converted during fermentation to nitric acid, viz. 0·0139 grammes, is 11·12 c.cs., a volume much in excess of that actually consumed (6·72 c.cs.)

It is impossible to suppose that this large excess of oxygen was derived from the quantity of peat present. Possibly intermediate combinations were formed during fermentation between the peaty matters and the nitrous acid, and that part at least of the nitric acid found after fermentation was formed from these combinations.

Unfortunately I have not yet been able to determine the relationship between the oxygen consumed and the nitrous nitrogen oxidized during this fermentation of nitrites in purely inorganic solution, a fermentation which Warrington has shown to be possible, by conclusively proving that nitric organisms develop in solutions containing nitrites and the necessary inorganic salts only.* Winogradsky, it should be observed, has confirmed this. I trust, however, in a future communication to give the results of some experiments I have already commenced with a view of determining this point, together with the results of a further study on the fermentation of peaty matter and ammonia, upon which I am at present engaged, with the object of completing the work of which the experiments I have given can only be regarded as forming the commencement.

Before concluding my references to the experiments recorded in Table XVI., I should like to draw attention to the results from experiment 2, as compared with those afforded by experiment 1 *a*, and recorded in Table XV. Those of the former experiment show an almost pure nitric fermentation, unaccompanied by either the formation or fixation of carbon dioxide, while those of the latter experiment show that the fermentation was a purely nitrous one, accompanied by the formation of a large volume of carbon dioxide. And yet in both dilute solutions of peat were employed, and each contained a decided excess of ammonia after fermentation. There was, however, one distinct difference between the two solutions. The peat solution employed for the experiment recorded in Table XVI. had undergone several stages of fermentation before being employed for this experiment, while the solution of peat employed for the other was a comparatively fresh one. We may therefore add an additional conclusion to those already drawn, viz. that the changes which peaty matters may undergo in the presence of decided quantities of ammonia, during fermentation may vary with their nature, *i. e.* whether they have themselves undergone fermentation previously or not (see p. 604).

* Warrington: "Researches on Nitrification, C.S.J., vol. lix., p. 519.

Nitrification of Pure Urea: An Exception.

As I have shown in the earlier part of this Paper, easily fermentable nitrogenous organic matter, when attacked by water-organisms under continued aërobic conditions, suffer two distinct stages of change, first, the organic carbon is nearly completely oxidized to carbon dioxide, and the organic nitrogen converted into ammonia; second, the ammonia thus formed is oxidized to nitrous or nitric acid.

That urea, when mixed with other organic substances, shows no exception to this rule has been proved by the researches of Warrington and of Munro, and also of other observers; the last-named observer has shown, indeed, that when this substance is mixed only with such a simple body as potassium oxalate,* the course of fermentation proceeds as above described.

The experiments which I have to describe were, however, made with simple solutions of urea in tap-water, containing in addition only a little sodium carbonate and potassium phosphate.

These experiments were commenced with two objects in view—(1) to ascertain whether nitrogen is evolved during the carbon stage of fermentation of urea, (2) to determine the nature of the nitrogen fermentation, which, it was anticipated, would follow the carbon fermentation.

The experiments were commenced in January, 1893, but the solutions were not examined again until nearly two years afterwards, and I was then surprised to find that even in a comparatively strong solution, containing as much as 0·05 grammes of urea per litre, a quantity of *nitrous nitrogen*, equal to 0·0016 grammes, had been formed, although it was apparently evident from the volume of carbon dioxide formed produced, at the same time, that not more than half the organic carbon originally present in the solution had been converted into that gas. It was feared, at first, that this was due to some leakage which might have occurred between the stopper and neck of the bottle in which the solution was preserved.

Accordingly, another set of experiments with urea was started, but this time with stronger solutions. A similar quantity of nitrous nitrogen was, however, again found, after fermentation, in a solution containing *ten* times the quantity of urea.

It accordingly seemed evident that urea, when *unmixed with other organic substances*, does undergo a change from the very commencement of fermentation, which apparently differs essentially in character from that of other easily fermentable organic substances so far as they are known. In the annexed Table will be found the particulars and results of the experiments above referred to.

* *Loc. cit.*, p. 640.

EXPERIMENTS COMMENCED JANUARY 4TH, 1893.

TABLE XVII.—*Experiments with Urea.*

Solution U contained 0·25 grammes urea = 0·05 grammes carbon, and 0·116 nitrogen,
0·10 sodium carbonate,
0·10 potassium phosphate,
} per litre.

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_3 I.	N as N_2O_3 II.	N as N_2O_5 I.	N as N_2O_5 II.
1894 Dec. 29	U/5	7·45	16·56	8·40	0·0	16·72	16·50	0·0	0·009	0·0	0·0016	0·0001	0·0002
	Differences, . .	+ 9·11		− 8·40		..	..	+ 0·009		+ 0·0016		+ 0·0001 ?	
,, 24	U/15	4·99	11·92	8·40	0·0	16·72	16·54	0·0	0·005	0·0	0·00288	0·0001	0·0012
	Differences, . .	+ 6·93		− 8·40		..	..	+ 0·005		+ 0·00288		..	..
,, 24	U/20	4·68	10·29	8·40	0·0	16·72	16·49	0·0	0·003	0·0	0·0014	0·0001	0·0019
	Differences, . .	+ 5·61		− 8·40		..	..	+ 0·003		+ 0·0014		+ 0·0018	
,, 28	U/40	4·22	7·49	8·40	0·0	16·72	16·51	0·0	trace	0·0	0·0016	0·0001	0·0021
	Differences, . .	+ 3·27		− 8·40		..	..	..		+ 0·0016		+ 0·0020	

EXPERIMENTS COMMENCED JANUARY 8TH, 1895.

Further Experiments with Urea.

Solution U′ contained 0·5 grammes urea = 0·10 grammes carbon, and 0·233 grammes nitrogen,
0·02 sodium carbonate,
0·10 potassium phosphate,
} per litre.

1895 Mar. 19	U′	8·06	17·54	8·46	1·75	16·83	16·88	0·0	0·006	0·0	0·0016	0·0001	0·0002
	Differences, . .	+ 9·48		− 6·71		..	..	+ 0·006		+ 0·0016		+ 0·0001 ?	
,, 21	U′/5	5·74	20·89	8·36	0·0	16·60	16·83	0·0	0·016	0·0	0·00208	0·0001	0·0002
	Differences, . .	+ 15·15		− 8·36		..	..	+ 0·016		+ 0·00208		+ 0·0001 ?	
,, 21	Tap-water, . .	5·11	5·16	8·46	8·44	16·87	16·83	0·0	0·0	0·0	0·0	0·0001	0·0001

We have unmistakable evidence in the above results, especially those afforded by the solutions U′ and U′/5, *that nitrous acid is formed in decided quantity simultaneously with ammonia, from the very commencement of the fermentation of urea, under aërobic conditions, and in the presence of the mixed organisms of a natural water.*

The results recorded for the solution U′ are particularly instructive, because since a small quantity of dissolved oxygen was found in the solution at the conclusion of the experiment, it may be taken for granted that the fermentation therein proceeded throughout its course, so far as it went, under aërobic conditions.

Under these conditions we find that the nitrous nitrogen formed was practically one-fourth the quantity of ammoniacal nitrogen produced at the same time, the former amounting to 0·0016 grammes, and the latter to 0·006 grammes.

The volume of carbon dioxide, viz. 9·48 c.cs., equal to 0·005 grammes carbon, which was simultaneously formed with these quantities of nitrous and ammoniacal nitrogen, is not in atomic proportion therewith, but is equivalent, it will be found, to a quantity of carbon much greater than such proportion would allow. It must, therefore, have been derived, in part at least, from some intermolecular changes set up in the portion of the urea fermented. If the composition of these bodies, or body, were known, we should then have, with the results recorded in the above Table, all the factors required for the precise formulation of the changes which urea undergoes during fermentation under the conditions given.

The study of this fermentation of pure urea by the method here employed became, in fact, of very great interest. To what, for instance, is this formation of the nitrous acid during the first-stage fermentation of urea analogous?

Is it analogous to the formation of the same body during true nitrification? I am inclined to think not. It is rather, I should say, to be classed with the oxidized organic bodies which we know are formed during the first-stage fermentation of more highly carbonated compounds, the nitrogen in the said nitrous acid substituting carbon, and this being possibly owing to the very small quantity of carbon contained in the urea, and to the chemical characters thereof. Before, however, this and other points suggested by the above experiments can be decided, a much more extended investigation will be necessary, and this, I hope, to commence shortly.

The fermentation in the solution U′/5 appears from the results recorded for it, to have proceeded further than in the solution just considered. A larger volume of oxygen was consumed, and a relatively larger quantity of nitrous nitrogen was formed. The carbon dioxide and ammonia were also increased, and in such large proportion that an anaërobic fermentation must, no doubt, have partially set in during the experiment.

Nitric Fermentation in Solution of Urea.

Turning once more to the results recorded in Table XVII., we notice that those afforded by the more dilute solutions U/20 and U/40 show that decided quantities of nitric acid were formed, but that apparently the nitrous acid first produced did not suffer further oxidation. This nitric fermentation may, however, have been brought about by the peaty matters in the tap-water employed for making up the solutions, and it is possible that *nitric* fermentation would not have set in in their absence. This is a question, however, which I must leave to a further communication.

Similar Quantities of Carbon Dioxide formed by Fermentation in Solutions containing similar Atomic Proportions of Carbon, as Urea, and as Potassium Sodium Carbonate.

It is interesting to compare the results with the above two dilute solutions of U, with those obtained from the dilutions IV/40 and IV/80 of the solution of potassium sodium tartrate employed for the experiments recorded in Table XI. These two sets of solutions contained similar quantites of carbon, the one as urea, and the other as tartrate. From the long time during which the solutions were kept, it may be taken that the peaty matter in the tap-water with which they were made up suffered fermentation as well as the added sustances. It is interesting to observe, therefore, that the volumes of carbon dioxide in each set are similar one to the other. (See also Tables VII. and XII.)

It will also be noticed that in both sets the conversion into oxidized inorganic products of the fermentable substances originally present in the solutions, must have been nearly quantitatively complete.

The Theory of Nitrification.

It seems to have been established from the researches of a number of observers, more especially from those of Mr. Warrington, Professor P. F. Frankland and Mrs. G. Frankland, Dr. Munro, and M. Winogradsky, that the nitrification effected by soil organisms is brought about by two species, one of which oxidizes ammonia to nitrates, while the other oxidize nitrites to nitrates.

These observers found that it was easy to obtain a nitrous fermentation in solutions of ammonia containing certain inorganic salts, but practically no organic matter, by means of organisms cultivated from soil. The attempt, however, to

obtain a nitric fermentation of ammonia under like conditions has, so far as I know, failed.

It was, however, perfectly well known that a nitric fermentation could be set up in inorganic solutions of ammonia, seeded by fresh soil. The question remained in obscurity until Warrington, in his last published "Researches on Nitrification," already referred to, showed that he had, in the course of his work, obtained some mixed organisms, some of which at least produced neither nitrous nor nitric acid from ammonia, but which energetically converted nitrites into nitrates.

Warrington showed further, that the presence of ammonia retarded the action of the nitric organisms on nitrites.

Winogradsky has since isolated, from soil cultivations, the organisms which has the power of fermenting nitrites to nitrates in inorganic solutions.

On referring to the experiments, which I have recorded on the fermentation of ammonia in the presence of peaty matters, and also, indeed, to such of those of other observers as were carried out in the presence of fresh soil, which it must be remembered no doubt contained organic bodies of a similar character and influence, in the shape of humus, to the peaty matters of my experiments, one cannot but be struck with the apparently direct influence of these matters on the fermentation. Thus, in the experiments 2, 3, 4, and 5, recorded in Table XV., the solution employed for which contained a large quantity of ammonia chloride relatively to the peaty matters, but in which the peaty matters were present in decided quantities, the nitric fermentation predominated, notwithstanding the fact that a considerable quantity of ammonia remained after the last experiment, No. 5; while with the more dilute solution in which the ammonia, so far as the fermentation was concerned, still remained large in quantity, but in which the peaty matters might be considered small in their relation to that of the ammonia, we get the reverse action shown, and the nitrous fermentation is seen to have predominated.

Again, if we refer to the experiments recorded in Table XVI., we find three solutions, all seeded with similar organisms, but differing markedly in other essential conditions:—

No. 1 is a purely inorganic solution, and in it a purely nitrous fermentation took place.

No. 2 contained peaty matters, and in it not only was a nearly pure nitric fermentation obtained, but the oxidized inorganic nitrogen product, in proportion to the oxygen consumed, was decidedly larger than in the case of solution 1.

Again, in solution No. 3, a nitric fermentation of nitrous acid is shown, in which the oxidized nitrogen product is, as in the case of the solution No. 2, theoretically equivalent to a much larger volume of oxygen than that actually consumed.

Here then, with the common condition of similar organism established in each solution, we get, in the absence of peaty matters, nitrous fermentation of ammonia, while in their presence we get a nitric fermentation of either ammonia or of nitrous acid.

The question therefore suggests itself—do not these peaty matters, when present in a water, exercise a dominating influence on the course of the fermentation of ammonia, and determine the nitric fermentation which is so noticeable concurrently with their presence?

I would go further and venture to suggest, that the explanation of the observed fact—that the nitrification of ammonia in a mass of aërated soil results normally in the production of nitrates only (Warrington)—is to be referred to the presence of organic substances in the soil, viz. humus, allied in character to the peaty matters of natural waters.

If this explanation be accepted, the question of nitrification would appear to stand thus:—

1. The nitrous organisms of soil thrive in inorganic solutions containing ammonia.

2. The nitric organisms of soil are gradually killed, or lose their vitality, in inorganic solutions containing ammonia.

3. The nitric organisms of soil thrive in inorganic solutions containing nitrites.

4. The nitrous organisms cannot oxidize nitrites to nitrates in inorganic solutions.

5. The presence of peaty or humus matters appears to preserve the vitality of nitric organisms during the fermentation of ammonia, and establishes conditions whereby it is possible for the nitric organisms to thrive simultaneously in the same solution with the nitrous organisms.

6. Query—Is it possible for either the nitrous, or nitric, or other organisms to separately set up the complete oxidation of ammonia to nitric acid, in the presence of peaty or humus matters?

PART III.

Bearing of the foregoing Experiments on the Analysis of Potable and Polluted Waters.

Up to the present time the bacteriological methods which have been proposed for the examination of waters have not resulted in bringing any very great practical assistance to bear on the subject of the technical examination of pure and polluted waters. I except, of course, those most important ones which can be employed for demonstrating the presence or absence of pathogenic organisms in a water. The suggestion that the number of microbes present in a given volume of water would give a useful indication or otherwise of its purity, from which so much was at first expected, has been shown, more especially in this country by the researches of Dr. P. F. Frankland,* to be of little practical value, except when applied for the examination of the efficiency of filtration, since many bacteria are capable of enormous and extraordinarily rapid multiplication even in waters of very high organic purity.†

Bacteriological research has been instrumental rather, as I observed in the introduction to this Paper, in demonstrating the true agencies at work in setting up processes of oxidation in waters, and in thereby indicating new lines of research for completing our knowledge of the chemistry of natural and polluted waters.

The experiments which have been described in this Paper, may, I venture to hope, prove a step onward in this direction, since they clear up, on the one hand, certain points in reference to the analysis of potable waters which have hitherto been more or less obscure; and, on the other hand, they indicate a satisfactory method for the examination and analysis of polluted waters.

First, as regards the examination of potable waters, these experiments show conclusively that (1) the absence of easily fermentable matters of all kinds, and (2) the indication that the water has been subjected to efficient artificial or natural filtration, are two conditions, positive evidence of which it is of the first importance to seek for in all waters to be used for dietetic purposes.

Broadly speaking the first condition will have been established if the water contains no free ammonia, or only small traces of this substance, since of the easily fermentable substances found in waters it is the last to be fermented.

The second condition will, no doubt, have been established, if, in addition to the absence of free ammonia, traces only of organic matter (fermented) are found in the water.

* "Proc. Roy. Soc.," 1886, p. 526.

† Article by Dr. P. F. Frankland, on "Water," already referred to, p. 990; see, also, work on "Micro-organisms in Water," by Dr. and Mrs. P. F. Frankland.

In reference to this point it must be remembered that during efficient filtration all but traces of peaty or humus matters are separated. Hence, the absence of all but traces of these matters and of ammonia may be accepted as one proof of efficient filtration in water.

That efficient filtration of all water to be used for dietetic purposes is a prudent precaution in the interests of health must be accepted from the property which bacteriologists have shown properly constructed filters to possess, of separating pathogenic organisms from water (Koch on Cholera, 1894).

It will be observed that the above two conditions in first-class potable water may be ascertained by the methods in ordinary use for water analysis.

In cases of doubt or suspicion, however, a careful examination of the character of the organic matters present should be made.

There can, I think, be no question that the method I have employed is capable of revealing both the nature and amount of polluting matters, should they be present in a water, or of proving their absence if not present. I can state from my own experience that examinations of such suspicious waters have afforded me results which have left no doubt in my mind as to their suitability or otherwise for dietetic purposes.

When we turn to the consideration of polluted waters, the matter assumes an entirely different aspect, for it is quite evident from the experiments which I have described, that the methods of analysis of potable waters, when applied to that of polluted waters, are not only quite incapable of indicating the true character of the polluting matters, but that they may even lead to absolutely misleading results.

From the experiments with polluted waters which I have recorded, it may be gathered that it is essential, in order to predict the action which a given volume of a particular polluted water will exert, when discharged into a watercourse of known volume and flow, to determine beforehand the exact volume of atmospheric oxygen which will be required for the complete fermentation of the polluting matters present, and that it is necessary also for technical purposes to approximately determine what fraction of that volume of oxygen is required for the first stage of fermentation of these matters. Under no circumstances ought a polluted water be discharged into a watercourse in such volumes that the dissolved oxygen in the mixture of the two waters, pure and polluted, is not more than sufficient to supply that required for the first-stage fermentation of the polluting matters.

This I consider is necessary, because the first stage of fermentation of easily fermentable organic matters proceeds much more rapidly in a water exposed to the atmosphere than does the solution and diffusion of atmospheric oxygen through the water. Hence, if the quantity of dissolved oxygen of a water is insufficient for the needs of this stage of fermentation of any polluting matters in it, putrefactive fermentation will set in.

It is otherwise with the second-stage fermentation of a polluted water, since this stage of fermentation probably does not proceed so rapidly in a water exposed to the same conditions as the diffusion of atmospheric oxygen into it, and since, if it does, secondary products of a poisonous nature, such as are formed during putrefaction, cannot be similtaneously formed with nitrous or nitric acid from the very nature of the process of nitrification.

It is right, therefore, in dealing with the question of the pollution of a water-course, to make this distinction between the oxygen required for the first stage fermentation and that required for the second stage.

I have made these remarks more particularly with the view of drawing attention to the possibility which the method of observation I have employed in this investigation presents, of formulating definite standards of impurity which should be allowed in the case of drainage waters discharged into a watercourse; it being possible, it should be observed, to formulate a standard according to local conditions and requirements.

A simple standard, which Local and River Conservancy Boards could control, could be framed as follows:—

The limit of impurity to be allowed to a given water to be such, that, when a given volume of it is mixed with a given volume of tap- or other good water, and the mixture kept in a bottle out of contact with air, under the conditions I have described, for a sufficient length of time, a decided oxidation of the ammonia originally present in the mixture into nitrous, or nitric, acid shall be indicated.

This is, howeover, merely a suggestion. Were the principle of the proposed standards adopted, experience would show how best to formulate them.

General Conclusions.

The following conclusions may be drawn from the experiments recorded in this Paper:—

1. That the method and apparatus described in the Paper for preserving natural waters, or artificial solutions, out of contact with air, and for analysing the gases in solution in them, before and after keeping, are capable of yielding very accurate results, and that the method is not attended with any great experimental difficulties.

2. That observations of the changes in composition of the gases in solution, which take place during the course of fermentation in the presence of mixed organisms, under the conditions described, when made in conjunction with an examination of the changes which simultaneously occur in the organic and inorganic nitrogenous bodies in the water, are productive of extremely important results, and are necessary if it be desired to investigate completely the chemical changes which accompany such fermentations.

3. That with the aid of such observations it is possible to study the various chemical changes which take place progressively during the fermentation within certain well-defined conditions of any fermentable substance or substances, from commencement to completion, at any intermediate step desired.

4. That it hence becomes possible to demonstrate that the fermentation of substances under aërobic conditions by the organisms usually present in water, takes place progressively in two distinct stages: (1) that in which the organic substances are completely broken down, the carbon and nitrogen being largely converted into carbon dioxide and ammonia, a little organic matter remaining as such, but in an altered form; and (2) that in which ammonia is oxidized to nitrous or nitric acids, or both.

5. That the first stage of fermentation must be complete before the second stage can set in.

6. That the *organic* substances which result as products of the first stage of fermentation, may undergo further change during the subsequent stage, and give rise to the formation of carbon dioxide, and possibly also to nitric acid.

7. That peaty matters when present alone in a water undergo very slow change, but when present with ammonium compounds, they readily undergo fermentation together with the ammonium compounds, just as the organic matters, which, as above stated, are formed during the first stage of fermentation of animal, vegetable, or artificial organic substances, do during the after-fermentation of ammonium compounds which may have been also formed thereby, or which may have been previously present or added.

8. That the presence of the above-mentioned fermented organic matters, or peaty matters, appear to determine the *nitric* fermentation of *ammonia*, since in their complete absence, similar organisms being present, only nitrous acid is obtained.

9. That during the intermediate stages of a fermentation of mixed peaty matters and ammonium compounds, various interchanges between the two appear to take place, the character and extent of which apparently depend upon the relative quantities of peaty matters, ammonia, and dissolved oxygen present, and also upon the character of the peaty matters themselves, whether they have been freshly formed, or have undergone any previous fermentative changes.

10. That in the presence of small quantities of peaty, or other fermented organic matters, carbon dioxide and ammonia may become "fixed," during fermentation in appreciable quantities, no doubt from Winogradsky's researches to form organic matter.

11. That the formation of one part by weight of nitrous nitrogen during the fermentation of ammonia, in the complete absence of organic matter, is attended by the consumption of about 4·2 parts by weight of oxygen.

12. That for similar volumes of oxygen consumed, the quantity of nitrogen oxidized during the fermentation of ammonia is distinctly greater, in the presence of peaty or other fermented organic matters, than in their absence.

13. That for similar volumes of dissolved atmospheric oxygen consumed, the quantities of carbon dioxide and ammonia "fixed" are also more appreciable in the presence of those organic matters during fermentation, than in their absence.

14. That from the earliest stages of an aërobic fermentation of a strong solution of pure urea, containing no other easily fermentable organic substances, *nitrous* nitrogen is formed in addition to ammoniacal nitrogen, in the proportion of about 1 : 4. It is possible that the chemical changes which here result in the formation of nitrous acid are not analogous to those attending the formation of nitrous acid in the fermentation of ammonia, but rather to those attending the formation of the oxidized organic matter during a first-stage fermentation, the nitrogen, in the case of urea, taking the place of the carbon in a more highly carbonated organic compound.

15. That by determining the changes in the dissolved gases, and in the organic and inorganic nitrogenous compounds, which accompany fermentation in natural and polluted waters, it is possible not only to differentiate easily fermentable from difficultly fermentable substances present, but to approximately estimate their quantity.

16. That such determinations are of very great value in the case of polluted waters, because in addition to affording very accurate estimations of the total quantities of fermentable matters in them, in terms of the exact volume of atmospheric oxygen necessary for their complete fermentation, it is possible by proper examination to determine what fraction of such volume is required for the first stage of fermentation, and what fraction for the second—distinctions of the utmost importance in considering the technical aspect of the pollution of rivers.

17. That in the course of the first-stage fermentation of some sewage-waters, there is some evidence to show that appreciable quantities of atmospheric nitrogen may be fixed.

Before concluding this portion of my study, it is due to my friend, Mr. James Carson, Assoc. R.C.Sc.I., to acknowledge the most valuable services which he has rendered me during the whole time I have been engaged upon this investigation. He has not only assisted me throughout in carrying out the very laborious analytical determinations incidental to the work, but has further assisted me by making and perfecting the mechanical arrangements of the beautiful model of my gas-analysis apparatus, which is described in this Paper.

[JANUARY, 1896.]

Abgegeben von Sternwarte Bamberg

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME V. (SERIES II.)

XII.

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BY GEORGE STEWARDSON BRADY, M.D., LL.D., F.R.S., AND THE REV. CANON ALFRED MERLE NORMAN, M.A., D.C.L., F.R.S., F.L.S.

(PLATES L. TO LXVIII.)

DUBLIN:

PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

WILLIAMS AND NORGATE,

14, HENRIETTA STREET, COVENT GARDEN, LONDON;

20, SOUTH FREDERICK STREET, EDINBURGH; AND 7, BROAD STREET, OXFORD.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK.

1896.

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(Plates L to LXVIII.)

COMMUNICATED BY PROFESSOR HADDON.

[Read January 23, 1895.]

In the first part of this Monograph* we described the species belonging to the Section *Podocopa*, to which belong the well-known genera *Cypris*, *Cythere*, and their allies, familiar to every microscopist who has dipped net into pond or sea. The sections of which we now treat are entirely marine in habit, and are for the most part scarce and difficult to obtain, being rarely or never found—in northern latitudes at any rate—except in the depths of the sea or swimming at some distance from the shore.

Of the species now described, the following are here recorded from the British seas:—

Section II.—Myodocopa.

Asterope Mariæ, Baird.
,, *teres*, Norman.
,, *elliptica*, Phillipi.
Crossophorus imperator, G. S. Brady.
Cypridina norvegica, Baird.
Philomedes brenda, Baird.
,, *interpuncta*, Baird.
Philomedes Mac Andrei, Baird.
Nematohamma obliqua, Brady and Norman.
Sarsiella capsula, Norman.
Conchœcia elegans, G. O. Sars.
,, *Haddoni*, Brady and Norman.
Conchœcilla daphnoides, Claus.

* "Trans. Roy. Dub. Soc.," vol. iv., 1889, pp. 63–270, Pl. VIII.–XXIII.

Section III.—Cladocopa.

Polycope orbicularis, G. O. Sars.
,, *punctata*, G. O. Sars.
Polycope dentata, G. S. Brady.
Polycopsis compressa, Brady and Robertson.

Section IV.—Platycopa.

Cytherella abyssorum, G. O. Sars.
Cytherella lævis, G. S. Brady.

We indicated our views in the first part of this Monograph, that for zoological purposes the North Atlantic should be considered as defined southwards by lat. 35° N., beyond which we would style the Ocean the Tropical Atlantic; but having received from the Marquis de Folin a number of abyssal forms taken by the French Government expeditions, in the "Travailleur" and the "Talisman," off the coast of Morocco, we have thought it advisable to include these species, inasmuch as living in very deep water at or near freezing point, it was probable that they would hereafter be found in the bed of the Atlantic further north. The species thus obtained consist of many most interesting forms which have been picked out by the Marquis from the dredged material of these expeditions, and for enabling us to describe the species we are deeply indebted to him. We have also included here the Mediterranean species, which were excluded from the *Podocopa* as being so numerous.

To Professor G. O. Sars we owe our sincere thanks for some Norwegian species. To Dr. John Murray we are indebted for some *Conchœciidæ* procured in the tow-net during the "Triton" Expedition in 1882, including the remarkable *Conchœcilla lacerta*. Mr. T. Scott and Mr. D. J. Scourfield we have to thank for their kindness in supplying us with specimens of some *Podocopa*, which are described in the Appendix.

To Professor Haddon we are indebted for a tow-net gathering from 220 fathoms taken 40 miles N. N. W. of Achill Head on the west coast of Ireland, which contained some very interesting *Conchœciidæ*.

In the Appendix just referred to will be found additional notes respecting the nomenclature &c., of certain forms contained in the former portion of this Monograph, as well as descriptions of new species since added to the fauna of N. W. Europe.

In consequence of the small size of *Ostracoda* it is extremely difficult to procure spirit-preserved specimens from the deep sea, and although the *Myodocopa*, being much larger than the *Podocopa*, would be detected by the experienced eye of a Carcinologist who had studied them, yet the Zoologists usually attached to

Government Expeditions cannot be expected thus to notice them. Hence it is that in a large number of cases the only examples which have come into our hands are such as have been picked out of dried material.

It struck us that, notwithstanding their dried condition, it might yet be possible by maceration to get some idea of the withered inmates of the shells. We therefore made experiments, and succeeded in restoring the animals beyond our most ardent expectations. All the portions of the animals figured in the genera *Streptoleberis*, *Tetragonodon*, *Paramekodon*, *Rutiderma*, also of the species *Asterope elliptica* and *teres* (♂), as well as in a great measure of *Cytherella*, have been taken from dissections of animals which have been preserved in a dried state for very many—in one case as long as twenty-three—years, and we are satisfied that these drawings will be found to be almost as exact, so far as they go, as those taken from spirit-preserved examples, though, no doubt, a seta or spine here and there, or other minute character, will be inexact, or not represented.

It was not until our Monograph was nearly completed, and on the point of going to press, that there appeared the splendid work of Herr. G. W. Müller on the Ostracoda of the Gulf of Naples. This work has, in the case of some few species, anticipated our descriptions, and we have, as far as possible, rectified our nomenclature in conformity with it. For the rest we have thought it best to let our MS. go to press as it was originally written.

The species belonging to this section described from the Mediterranean by Müller, but not noted by us, are the following:—

Cypridina squamosa,	G. W. Müller.	*Polycope tuberosa*,	G. W. Müller.
Philomedes aspera,	,,	,, *maculata*,	,,
,, *lævis*,	,,	,, *reticulata*,	,,
Pseudophilomedes angulata,	,,	,, *frequens*,	,,
Sarsiella lævis,	,,	,, *striata*,	,,
Cylindroleberis Lobianci,	,,	,, *fragilis*,	,,
Archiconchæcia striata,	,,	,, *dispar*,	,,
Conchæcia procera,	,,	*Polycopsis serrata*,	,,
,, *rotundata*,	,,	*Cytherella sordida*,	,,
Polycope rostrata,	,,		

As an introduction to this part of the Monograph we here give a synopsis of some distinguishing characters of the sections and families. For fuller account of the families of the *Podocopa* we would refer to pp. 65–67 of the first part of this Monograph.

OSTRACODA, Latreille, 1802.

Synopsis of Sections and Families.

Section I.—**Podocopa**, G. O. Sars, 1865.

Antennæ simple, sub-pediform, geniculate, furnished with ungues, in other respects not very unlike the antennules. Both antennules and antennæ either bear long setæ, being thus adapted for swimming, or are shortly setose, when the only means of progression is walking. First maxillæ always furnished with a branchial appendage. Caudal laminæ either rudimentary, or when developed consisting of slender, elongated laminæ, with few terminal ungues.

A. Last three limbs pediform, without branchial appendage. Mandible simple, very narrow and stiliform (without palp or branchial appendage), enclosed in a tube formed by the labrum and labium, the whole apparatus adapted for suction. Caudal laminæ rudimentary. Fam. *Paradoxostomatidæ*, Brady and Norman, 1889.

B. Last three limbs pediform, without branchial appendage. Mandible toothed and adapted for chewing, furnished with a sub-pediform palp and a branchial appendage. Caudal laminæ rudimentary, in the form of setiferous lobes. Fam. *Cytheridæ*, Baird, 1850.

C. Last three limbs pediform, the first with a branchial appendage. Mandible nearly as in *Cytheridæ*. Caudal laminæ not developed, represented by a small sub-conical process. Fam. *Darwinulidæ*, Brady and Norman, 1889.

D. Last three limbs pediform, the first of these with a branchial appendage. Mandible nearly as in the *Cytheridæ*. Caudal laminæ not large, narrow, linear, furnished with terminal ungues as in *Cypridídæ*. Fam. *Bairdiidæ*, G. O. Sars, 1887.

E. Only last two limbs pediform; the preceding pair small and maxilliform in female, larger and modified for grasping in male; furnished with a branchial appendage. Mandible nearly as in *Cytheridæ*. Caudal laminæ long, narrow, linear, terminating in ungues. Fam. *Cypridídæ*, Baird, 1850.

F. As *Cypridídæ*, but the caudal appendages minute, consisting of setiform processes, which run out to a very fine extremity. Fam. *Cypridopsidæ*, Brady and Norman.

Section II.—**Myodocopa.**

Antennæ two-branched; basal joint very massive and large, subcordate or pyriform; larger branch natatory, its first joint long, naked, followed by many short setiferous joints; secondary branch usually minute, sometimes absent, in male generally rather larger, and formed for grasping. Antennules scarcely natatory, except in males. Mandibular palp very large, geniculate; subpediform, destitute of branchial appendage. First maxillæ without branchial appendage. Caudal laminæ broad, flattened, hinder margin beset with ungues.

* All limbs posterior to the first maxillæ pediform or subpediform.

Last limb minute, consisting of two articulations. No eyes or ocellus. Antennules short, in ♀ weak, indistinctly articulated, immoveable; in ♂ larger, articulated, with long terminal setæ. Mandibles with well developed teeth. Small vibratory laminæ attached to penultimate and antepenultimate pediform limbs. Caudal laminæ broader than long. Fam. *Conchœciidæ*, G. O. Sars.

** Limbs posterior to the first maxillæ not pediform or subpediform; last limb in the form of an elongated, flexible, annulated, vermiform organ of great length, curved upwards and backwards, ending in two lips, and furnished at and near the extremity with long, delicate spines, which are barbately spinulose at their apices. Antennules large, 5–7 jointed, geniculated at the end of first joint, with long setæ at the extremity. Mandibles without teeth. Eyes generally present and compound, pedunculated, widely separated, and also between them a simple eye. Large vibratory laminæ attached to the antepenultimate, and usually also to the penultimate limbs. Caudal laminæ oval or subtriangular, longer than broad. Ova carried within the shell behind the body.

1. Antennules having a terminal unguis as well as setæ. Mandible with a recurved, falciform, toothed process. First maxillæ consisting of only two lobes, one elongated, triangular, naked; the other thin, membranous, falcate, ending in two setæ, and having the inner edge closely set with pectinately arranged, very long setæ. Second maxillæ consisting of a single, flattened, unjointed member, curiously twisted in the middle, its inner margin edged with setæ; vibratory lamina large. Third maxillæ simple, subtriangnlar; distal edge setose; no vibratory lamina. Animal furnished at the back of the hinder portion of the body with two series of membranous, lamelliform branchiæ. Fam. *Asteropidæ*, Brady and Norman.

2. Antennules without a terminal unguis. Mandible with or without a small simple or bifid hirsute process near the base; the palp ending in ungues. First maxillæ many-lobed, and furnished with a subpediform 2–3 jointed palp. Second maxillæ minutely-lobed, the last lobe generally furnished with distinct teeth; a small unjointed, sometimes three-lobed, palp. Third postoral appendages also maxilliform. No branchiæ.

A. Shell with a deep sinus in front for the protrusion of the antennæ; anterior extremity projected in rostrate or subrostrate form. Mandible palp ending in ungues. Teeth of second maxillæ varying in form in different genera. Fam. *Cypridinidæ*, Baird, 1850.

B. Shell oval, truncate behind, antennal sinus very shallow, a mere sinuation of the margin; surface of valves rugose. Antennules (♀) without sensory organ. Antennæ without any secondary branch. Mandible—palp with last joint of great size, ending in a distinct and large chela. Second maxillæ furnished with tooth. Fam. *Rutidermatidæ*, Brady and Norman.

C. Shell oval or round, no antennal sinus. Last three joints of mandible—palp very short, without setæ, each furnished with a well-developed unguis. Second maxillæ without teeth. Fam. *Sarsiellidæ*, Brady and Norman.

Section III.—**Cladocopa**, G. O. Sars, 1865.

Antennæ two-branched, both branches well developed, moveable and natatory. Antennules also natatory, not geniculate, ending in long setæ. Mandibles distinctly toothed, with two-jointed palp, the first of which carries a small branchial appendage. Only two pair of appendages posterior to the mandible, the first bifid and natatory, the second membranaceous and branchial. No eyes. Caudal laminæ short, their posterior margin spinose and unguiferous. Fam. *Polycopidæ*, G. O. Sars, 1865.

Section IV.—**Platycopa**, G. O. Sars, 1865.

Antennæ two-branched, flattened, resembling the feet of Copepoda; basal portion biarticulate and geniculate; branches flattened, composed of few joints, and bearing many setæ on both margins. Antennules very large and strong,

many-jointed, geniculated at the base, shortly spiniferous. Mandibles small and weak, palp large. Three pair of limbs posterior to the mandibles, all maxilliform. Palp of the mandibles and first maxillæ bearing internally a comb of large setæ. First and second maxillæ furnished with a large vibratory lamina. Third pair rudimentary in the female, in the male well developed and prehensile. Caudal laminæ small and narrow, spiniferous at the extremity. Fam. *Cytherellidæ*, G. O. Sars, 1865.

Section II.—Myodocopa.

Shell ovate, elongated-ovate, or round, sometimes truncate behind, and often produced to less or greater length at the infero-posteal corner, or sometimes at the supero-posteal corner. On the lower portion of the front margin there is usually a sinus for the protrusion of the antennæ, and above this the shell is projected in more or less rostrate form. Valves highly calcareous, or thin and almost membranaceous; surface smooth and polished, or hispid, sometimes reticulated; at others pitted or roughly sculptured.

Eyes, usually two, pedunculated, or rudimentary, or even absent in some cases: a central ocellus, except in *Conchæciadæ*. Always a frontal tentacle of greater or less length, simple except in *Conchæciadæ*, where it is more developed, and usually has an expanded, distal, articulated process (capitulum).

Antennules not adapted for swimming, generally with sensory appendages, which are variously modified, for the most part of considerable size, but small in *Conchæciadæ*. Antennæ always consisting of an immensely strong, muscular, pyriform or subcordiform basal joint, and a multiarticulate branch, the basal joint of which is long, the rest short, and all, except the first joint, furnished with long annulated setæ, which always in ♀, and usually in ♂, are plumose, and form a powerful swimming organ: a secondary branch—usually, but not always, present in ♀—when present minute; in ♂ more developed, and usually (not in *Cypridina*) formed for grasping, the last of the two or three joints folding back upon the preceding.

The labrum and labium are little developed; largest in the *Conchæciadæ*. In *Conchæciadæ* only is the mandible provided with teeth, but is often furnished with a simple or bifid hirsute, or a reflexed falcate process in their place. Attached to the mandible is a 3–4 jointed palp, the first joint of which, in genera provided with the hirsute or falcate process just referred to, is furnished with some peculiarly modified spines: the palp usually ends in one or more ungues, but in *Rutiderma* a strongly-developed chela takes their place.

The first maxillæ are furnished with several lobes and a two-jointed palp, the terminal joint incurved, and terminating in spines or ungues. Second and third maxillæ in *Asteropidæ* are in the form of very simple, seta-edged laminæ; in *Cypridinidæ*, *Rutidermatidæ*, and *Sarsiellidæ*, maxilliform, consisting of one or several lobes, and behind furnished with thin, seta-surrounded vibratory laminæ. In *Conchœciadæ* these limbs are still small, but many-jointed, pediform, and ending in ungues, while the vibratory laminæ are greatly reduced in size.

The last limb in the *Conchœciadæ* is very minute, and consists of two little joints, the last terminating in setæ. In all the other families this limb assumes a remarkable and very distinctive character; it is long, cylindrical, and closely annulated, and thus vermiform, and is carried reflexed upwards and backwards: its extremity is divided into two lip-like lobes, which are pectinately cleft, or otherwise variously formed in the different species: around this extremity of the limb, and also on the sides at a short distance behind it, are numerous long spine-like appendages, which are themselves armed with a few aculeate projections on each side towards their extremities.

The caudal laminæ remind us of those of the *Cladocera:* they consist of a pair of plates, commonly elongated, but sometimes not so long as wide, their margins beset with numerous ungues, which gradually increase in length to the end. In most of these families a heart is present. The *Asteropidæ* alone are provided with a series of dorsal branchial plates. The ova are carried in most genera, as in the *Cladocera*, within the shell behind the hinder portion of the animal, which is attached to the shell by dorsal and lateral muscles about the middle of its length.

Of the very remarkable genus *Heterodesmus*, described by one of us in the "Transactions of the Zoological Society" for 1865, nothing is known except the shell. It seems, however, to be nearly allied to the fossil genus *Entomoconchus*, M'Coy, and probably will be found to belong to the group *Myodocopa*.

Fam. 1.—**ASTEROPIDÆ**, Brady and Norman.

Shell more or less oblong or elliptical, smooth, glabrous, deeply incised in front, rostral portion widely rounded, little produced downwards; posterior extremity in ♀ well rounded; in ♂ lips of valves slightly pouting behind. Antennules short and stout, penultimate joint in both sexes furnished with an unguis, antepenultimate bearing a conspicuous sensory organ of different structure in the two sexes; apical setæ subequal in ♀, in ♂ two of these setæ are excessively long. Mandibular foot very strong; basal joint with a large, reflexed, falcate masticating process, which is denticulate on the edge. First, second, and third maxillæ all thin and membranaceous, and fringed in almost all parts with setæ,

but furnished with no spines or teeth. Vermiform limb as usual. Caudal laminæ very short, the extremity beset with ungues. Seven pairs of imbricated, elongated, thin branchial lamellæ on the back of the hinder portion of the body.

The family is widely separated from other *Myodocopa* by the peculiar structure of the three pairs of maxillæ, and the presence of dorsal branchiæ.

Genus Asterope, Philippi, 1840.

(= Copechœte, Hesse, 1879.*)

Shell more or less oblong or elliptical, polished, smooth, in male rather larger than in female, and higher behind, where the edges are also more pouting. Eyes well developed in both sexes. Frontal tentacle long and slender. Antennules of female with sensory organ on antepenultimate joint terminating in a flabellately divided extremity mounted on an annulated pedicel (Pl. L., fig. 3); in male in the form of a large densely setose, robust, annulated seta (Pl. L., fig. 2). Antennæ, with swimming branch well developed, appendicular branch in ♀ small, ending in a seta, in ♂, three-jointed, formed for grasping (Pl. L., figs. 4, 10); last joint falcate, reflexed on the second. Mandibular foot strongly built; basal joint with a large falcate, reflexed, masticating process, serrated on the edge at the tip (Pl. L., fig. 6); second joint, with a backward directed lobe at the base, furnished with a few spines of very peculiar structure (Pl. L., fig. 9): limb terminating

* M. E. Hesse, in 1879, published a paper in Ann. Sci. Nat. Zool., 6e ser., vol. vii., p. 1–20 (separate copy), pl. xii.—"Description des Crustacés rares ou nouveaux des côtes de France. Vingt.-huitieme article"—in which he described a genus *Copechœte* with four species, and a family *Copéchétiens*, which he placed among the Cladocera and next to the Bosminidiens. His genus *Copechœte* is undoubtedly a synonym of *Asterope;* but what his species are it is impossible, from the descriptions and extraordinary drawings, to say—possibly *Copechœte elongata* and *affinis* are referable to *A. elliptica*, Phil., and *C. armoricana* to *A. teres*, Norman.

Herr. G. W. Müller, in his recently published work, "On the Ostracoda of the Gulf of Naples and adjacent Sea," adopts instead of *Asterope* the generic name *Cylindroleberis*, his reason for this course being, that the term *Asterope* had been proposed also by Müller and Troschel for a genus of Echinodermata, simultaneously (1840) with Philippi's publication of the same name for the genus of Ostracoda now under consideration. It is doubtful, however, which of the two memoirs (Philippi or Müller and Troschel) was first in the field; we therefore think it best, to adhere, for the present, to the name *Asterope*, by which this genus of Ostracoda is best known. Should this name prove to be later in date than that of Müller and Troschel, we shall, of course, have to follow Herr G. W. Müller in adopting the generic term *Cylindroleberis*, which was applied to the group by one of us in 1868.

Müller and Troschel formed their genus *Asterope* to receive a starfish, which, in the same year, J. E. Gray also took as the type of a new genus, *Gymnasteria*. Sladen, in "The 'Challenger' Report—Asteroidea," uses the latter name on account of the doubt in date of the two *Asteropes;* but if the Echinoderm *Asterope* antedates that of the Crustacean it must undoubtedly be used, inasmuch as Gray's genus was not published until the end of the year (December 1).

in more than one unguis. First maxillæ (Pl. li., figs. 14, 15) consisting of a falcate main limb ending in two setæ, beset all round the inner margin with long and slender setæ pectinately arranged; in front, from the base of this main limb, is given off a narrowly triangular membranaceous, naked lamella. Second maxillæ (Pl. lii., fig. 16) consisting of an undivided, thin, linguiform lamina, which is curiously half bent round on its axis in the female, but not so bent in the male, and setose on the inner margin; behind this is a large, semicircular vibratory lamina, surrounded by pectinately arranged, long plumose setæ. Third maxillæ in the form of a subtriangular, or shoe-shaped, undivided lamina beset throughout the greater part of the distal margin with short plumose setæ. Vermiform appendage (Pl. lii., figs. 18, 19) as usual in *Myodocopa*. Caudal lamina broader than long, with numerous ungues (Pl. lii., fig. 22),, which gradually increase in length to the extremity. Dorsal branchiæ (Pl. l., fig. 1; Pl. lii., fig. 21), seven pairs of considerable size, and partially overlapping each other.

1. **Asterope mariæ** (Baird).

(Pl. l., figs. 1–6; Pl. li., figs. 11–22; Pl. lii., figs. 10–15.)

1850. *Cypridina mariæ*, . . Baird, "Proc. Zool. Soc.," p. 257, pl. xvii., figs. 5–7.

1859. ,, *oblonga*, . . Grube, "Ueber Cypridina und ein neue Art dieser Gattung.," Archiv. f. Naturges., p. 322, pl. xii. ♀ (*fide* G. O. Sars. We have not this paper).

1861. ,, ,, . . Grube, "Ein Ausflug nach Triest und dem Quarnero," pp. 101–107, pl. v., figs. 2–5, &c., ♀.

1867. *Cylindroleberis mariæ*, Brady, G. S., "Synopsis of Recent British Ostracoda," Intellectual Observer, p. 127, pl ii., figs. 11–14, ♂, ♀.

1868. ,, ,, Brady, G. S., "Mon. Recent Brit. Ostrac.," Trans. Linn. Soc., vol. xxvi., p. 465, pl. xxxiii., figs. 18–22; pl. xli., fig. 1, *a–h*, ♂, ♀.

1887. *Asterope oblonga*, . . Sars, G. O., "Nye Bidrag til Kunds. om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," Archiv. for Mathem. og Naturvid., p. 31 (separate copy), pl. i., figs. 5–8; pl. ii., figs. 1, 2; pls. v., vi., ♂, ♀.

1894. *Cylindroleberis oblonga*, Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 219, pl. iv., figs. 14–18, 39, 41, 49–55; pl. v., figs. 1, 4, 5, 13, 14, 33, 41–44; pl. viii., fig. 4.

Shell of the female (Pl. LII., figs. 14, 15) narrow and subcylindrical in outline, more than twice as long as high; ventral and dorsal margins almost straight and parallel throughout the greater part of their length, the arcuation being confined to the extremities, both of which are obtusely rounded; antennal sinus very narrow, but deep, situated a little below the middle of the anterior margin; valves highly calcareous, smooth, white. Seen from above the greatest width is behind the middle, whence the sides slightly converge forwards; anterior extremity narrower than the posterior.

Shell of the male (Pl. LII., figs. 12, 13) having the greatest height anterior; ventral margin straight; dorsal slightly arcuated throughout, and the declination both in front and behind less sudden than in the female; posterior extremity vertically truncate, with a slight protusion at its junction with dorsal margin. Antennal sinus much more gaping than in female, its lower margin being horizontal instead of projected obliquely forwards, which is the case in the other sex. Seen from above the greatest width is near the front, and the anterior extremity is wider than the posterior. Length of female 2·4 mm.; height 1 mm.

In the ♀ the antennules (Pl. L., fig. 3) have the second joint rather shorter than the first, and all the following successively decrease in length; first joint naked, second with one plumose seta on the inner margin, and one small seta on the side; third with seven setæ on inner margin, of which the five proximal are plumose, the two distal longer, ringed, but not plumose, outer margin with a minute spinule at the base and two ringed setæ at the extremity, this joint is subquadrate in form; fourth joint bearing, at the distal extremity of the outer margin, a sensory organ consisting of a very closely annulated basal portion, which is ultimately flattened out, and then split into six thong-like processes, which are spread on one plane; fifth joint with one small seta on the middle of distal margin, which below carries a conspicuous unguis; last joint with five annulated setæ, from which are thrown out numerous long lashes.

Antennæ (Pl. L., fig. 5) having the swimming branch bearing eleven setæ, of which four are at the extremity, the three most distant smaller than the rest, the last being minute; secondary appendage three-jointed, but apparently imperfectly segmented, last joint terminating in a seta, and another minute seta near the extremity. On Pl. L., fig. 5, we have represented an abnormal condition of this organ, which on both the antennules of the specimen from which the drawing is taken was of much larger size than usual and entirely without setæ.

The frontal tentacle (Pl. LI., fig. 11) is long and slender.

The mandible (Pl. L., fig. 6) is furnished below with a large falcate, reflexed process, the hinder margin of which is armed with four obtuse serrations, and nearer the base a single plumose seta: palp four-jointed, the first joint with three

ringed setæ on the upper margin, one in the middle, the others near the extremity, and to the extremity itself is attached a very small laminar appendage ending in two small setæ; below, the proximal corner is produced backwards into a triangular lobe tipped with four small plumed setæ, beyond which are four organs of remarkable character; with a low power they look like ordinary spines, but when highly magnified it is seen that they consist of an attenuated basal portion and an expanded spear-shaped extremity (Pl. L., fig. 6 *a*); the distal half of the basal portion, moreover, is annulated and also ciliated, and the spear-shaped extremity under a very high power is seen to be tridentate; second joint of palp with a fascicle of three long, ringed, and ciliated setæ on the middle of the inner margin; outer margin of the third joint covered with setæ nine in number, the first slender, the next two stouter, after which slender and stouter setæ are arranged alternately, lower margin with three setæ at the extremity; last joint with a strong unguis above, below which are five setæ.

None of the three following organs are furnished in any part with either ungues or spines, but are invested everywhere with plumose setæ. The first maxillæ (Pl. LI., figs. 14, 15) are of remarkable form; they consist of an unjointed, gradually acuminated main member, which is bent back upon itself, so as to form a bow; the outer margin is smooth, the inner densely covered almost throughout with long plumose setæ; just before the end of the reflexed extremity the setæ cease, but the extremity itself terminates in two simple setæ; within the margin at the base is a group of setæ of larger size: on the outer side of this main member is a second in the form of a flattened, triangular, naked process, which is not half the length of the main member.

The second maxillæ (Pl. LI., fig. 16) consist of a single strap-shaped member, narrowly rounded at the extremity, fringed on the inner side with plumose setæ, and twisted half round in the middle of its length in the female, but not twisted in the male; behind this is a very large semiovate, vibratory lamina, surrounded with long plumose setæ.

The penultimate limb (fig. 17) consists solely of a subtriangular or shoe-shaped plate, margined with short plumose setæ.

The vermiform limb (fig. 18) has about twelve spines of the usual character, six of which are at the extremity; these spines (fig. 19) have four pairs of spinules towards the extremity.

The caudal laminæ (fig. 22) have ten ungues, the upper five small, the following five larger, and successively increasing in size to the last.

The hinder portion of the body is furnished dorsally with seven pairs of overlapping, elongated membranaceous respiratory lamellæ (Pl. L., fig. 1).

In the male the antennules (Pl. L., fig. 2) are six-jointed, second joint longer than the first, with one large, plumose, backward-curving seta on the middle

of the upper margin; third joint triangular with six plumose setæ on upper side, three of which curve backwards; fourth joint with one seta above, and, at the extremity below, a very large sensory organ of entirely different character from that of the female, it is here a stout process, tapering to a fine extremity, very closely ringed throughout, and densely beset everywhere with fine filamentary threads; fifth joint with one small seta on the face, and at its lower corner giving support to the terminal unguis; last joint with two very stout and immensely long ringed setæ, which are beset with lashes here and there throughout their length, and three short setæ. The antennæ (Pl. L., fig. 4) have the second joint of the swimming branch equal in length to 4–5 following joints, the setæ as in ♀; appendicular branch larger than usual, forming a strong grasping organ, first joint of equal width throughout, about four times as long as wide (Pl. LI., fig. 12); second joint as long as, but wider than the first, widening from the base to the commencement of the palm, against which the unguis impinges, thence the front margin slopes backwards to the extremity, and bears in the middle three short setæ; unguis large, arcuate, widest in the middle, acute at the extremity, a seta behind its base. The mandibular foot (Pl. XLVI., fig. 13) is almost exactly as in the female, the basal joint has the same falcate process, and the second joint similar spear-shaped organs.

Habitat:—"Isle of Skye" (Baird). Shetland; Tobermory, in the Isle of Mull; off Tarbert, Loch Fyne, 20–60 fathoms; Valentia, Ireland; Penzance; Plymouth; Herm (A. M. N.). Cumbrae (D. Robertson). Jersey (Sinell), north-east coast of England, 25–35 fathoms (G. S. B.). Scilly Islands and Mulroy Lough, Co. Donegal (G. S. B. and D. R.).

Distribution.—Isle of Cherso, in the Adriatic (Grube). Spezzia, Messina, Goletta, and Syracuse, 5–20 fathoms (G. O. Sars). Bay of Biscay, at Cape Breton (Marquis de Folin). Hardanger Fiord, Norway (G. O. Sars).*

* *Vide* Undersögelser over Hardangerfjordens Fauna," 1871, Vidensk.-Selsk. Forhand., p. 279. This was published subsequently to his descriptions of *A. norvegica* and *A. abyssicola*, so that, perhaps, the omission of *A. mariœ* in the list of *Ostracoda*, in his recent published paper, "Oversigt af Norges Crustaceen, II. *Branchiopoda*, *Ostracoda*, *Cirripedia*," Vidensk.-Selsk. Forhand. Christ., 1890, p. 15. was accidental.

2. **Asterope elliptica**, Philippi.

(Pl. lii., figs. 16, 17; Pl. lix., figs. 19, 20.)

1840. *Asterope elliptica*, . . "Archiv. f. Naturgesch.," p. 188, pl. iii., figs. 9–11, ♀. Translated "Ann. & Mag. Nat. Hist.," vol. vi., 1840, p. 94, pl. iii., figs. 9–11.

1887. ,, ,, Sars, G. O., "Nye Bidrag til Kunds. om Middelh. Invertebratfauna: iv. Ostracoda Mediterranea," Archiv. for Mathem. og Naturvid., p. 28, pl. i., figs. 1–4; pl. iv., ♂, ♀.

Shell in female (Pl. lii., fig. 16, 17) elliptical, well rounded at the extremities, height equal to half the length, ventral margin very slightly arcuate, dorsal rather more arched, anterior two-thirds of shell higher than posterior third, in this respect differing from *A. mariæ;* antennal sinus below the middle of the front, and opening more downwards than in *A. mariæ*, the rostrate anterior process overhanging it. Seen from above, the greatest width is central, and the ends nearly equal. The shell of the male, according to Sars, is both higher and broader in front than behind, dorsal margin irregularly curved; posterior extremity obtusely truncated; anterior above the antennal sinus somewhat cut away. In the female the antennules (Pl. lix., fig. 19) have the third joint much shorter than the fourth, its distal margin concave, so that it is longer above and below than in the middle; the terminal nail is long and slender, subequal to the last two joints in length. The mandibular palp (Pl. lix., fig. 20) not only has the peculiar spines of the infero-anteal lobe distinctly trident-formed at the extremity, but also spined or serrated on the margin of the stalk; the appendage at the end of the second joint is two-thirds as long as the third joint; the terminal unguis is long and slender, sub-equal in length to the last two joints. Caudal ungues eight pairs. Length of female, 1·5 mm.

Sars says that the terminal nail of the appendicular branch of the antennæ in the male—which we have not seen—is scarcely more than half the length of the preceding joint, and boldly curved in the middle.

Habitat.—Off Valentia, Ireland, 1870 (A. M. N.).

Distribution.—Fosse de Cap Breton (Marquis de Folin). Palermo, Sicily (Philippi). Messina, 10–20 fathoms (G. O. Sars).

3. **Asterope norvegica**, G. O. Sars.

(Pl. LII., figs. 7–9.)

1869. *Asterope norvegica*, . . Sars, G. O., "Undersögelsen over Christianiafjordens Dybvandsfauna," p. 53.

The following are the describer's characters of the species:—

Shell of female smooth, elongated ovate or elliptical; greatest height sub-equal to half the length; ventral and dorsal margins equally convex; obtusely rounded at both extremities. Seen from above, narrowly ovate; greatest width rather behind the middle; extremities obtuse. Antennal sinus situated nearly in the middle of the anterior extremity, very narrow, inclining obliquely upwards. Eyes distinct; antennules very strongly built, composed of six articulations, the first the longest, the second rather longer than the following, upper margin with one densely ciliated seta which curves backwards; third and fourth imperfectly jointed with five setæ on upper margin; penultimate joint with a short annulated sensory appendage furnished, at the extremity, with six olfactory papillæ; last joint terminating in a strong unguis and six short setæ. Antennæ of the usual form, natatory branch composed of nine articulations, the setæ long; first joint scarcely longer than the length of the rest combined; appendicular branch very small, indistinctly three-jointed, with one terminal seta. Mandibular feet short and robust; basal joint (the mandible itself) large and thick, not provided with any biting processes; second joint with a short lobe on the inner side armed with six "aculei"; distally above, with a small laminar appendage and two ciliated setæ; penultimate joint short, scarcely twice as long as broad; upper margin beset with about six thick annulated setæ; last joint very small, armed with a nearly straight unguis and four setæ. . . . Vermiform appendage with ten unequal spines. Caudal laminæ very small, as broad as long, armed with five ungues which rapidly increase in length towards the extremity, and above the ungues two short setæ. Colour white; length 1·34 mm.

Holmestrand, in the Christiania Fjord, Norway, in 50–60 fathoms, muddy bottom (G. O. Sars). Our figures are taken from specimens for which we are indebted to Professor Sars.

4. **Asterope abyssicola**, G. O. Sars.

(Pl. lii., figs. 18, 19.)

1868. *Asterope abyssicola*, . . Sars, G. O., "Nye Dybvandscrustaceer fra Lofoten," Vidensk.-Selsk. Forhand, p. 170.

Shell of female, seen from the side, elongated-ovate; greatest height rather in front of the middle, equal to rather more than half the length; ventral and dorsal margins somewhat irregularly arched, hinder extremity evenly rounded; anterior extremity higher, and roundly-truncated; antennal sinus very narrow, situated slightly below the middle, slightly inclined upwards. Seen from above the form is narrowly ovate, more attenuated in front than behind, greatest width central and less than the height. Valves glabrous, shining, white, altogether destitute of hairs. Eyes wholly absent. Antennæ, mandibular foot, and maxillæ almost exactly as in *A. norvegica*, but the vermiform appendage furnished with more (15–16) spines. Caudal laminæ short, armed with five ungues, increasing in length towards the extremity. Length, 1·32 mm.

Very rare, Lofoten Islands, in 120 fathoms (G. O. Sars).

The above are the characters given by Sars for the species, and our figure of the shell of the ♀ is taken from a specimen kindly given to us by the describer.

5. **Asterope teres** (Norman).

(Pl. l., figs. 7–10; Pl. lii., figs. 20, 21.)

1861. *Cypridina teres*, . . . Norman, "Contributions to British Carcinology," Ann. & Mag. Nat. Hist., ser. 3, vol. viii., p. 8 (separate copy), pl. xiv., fig. 10.

1867. *Cylindroleberis teres*, . . Brady, G. S., "Intellectual Observer," p. 128.

1868. ,, ,, . . Brady, G. S., "Monograph Recent British Ostracoda," Trans. Linn. Soc., vol. xxvi., p. 465, pl. xxxiii., figs. 6–9; pl. xli., fig. 2.

(?) 1876. *Asterope oblonga*, . . Claus (*nec* Grube), "Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, p. 92, &c., pl. xvii., figs. 1–10.

1894. *Cylindroleberis teres*, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 220, pl. iv., figs. 13, 30; pl. v., figs. 15, 24, 25; pl. viii., fig. 5.

Shell of female (Pl. lii., figs. 20, 21) regularly oval, greatest height rather behind the middle, equal to fully two-thirds of the length; ventral and dorsal margins both well arched throughout, the latter rather more boldly than the former; posterior extremity very broadly and evenly rounded; anterior extremity narrower than the posterior; antennal sinus very narrow and shallow, situated below the middle, and nearly erect; rostral process moderately wide at the extremity, and bending over the antennal notch. Seen from above the form is more tumid than in other species of the genus; greatest breadth near the hinder extremity, which extremity is much broader than the anterior, and well rounded, sides arcuately sloping forwards. Surface of valves white, polished, finely punctated, glabrous. Length 1·6 mm. Third joint of the antennules (Pl. l., fig. 8) much shorter than the fourth, divided diagonally so as to form two triangular joints, the outermost of which bears eight closely-packed marginal setæ; sensory organ as in *A. mariæ;* unguis long and slender, its edge crenated; terminal setæ very long, the setæ themselves terminating in lashes of similar character to those which spring from their sides. Appendicular branch of antennæ papilliform (fig. 7), scarcely more than twice as long as its greatest width, indistinctly articulated, the end rounded, and bearing a long terminal seta, which is the only seta the limb bears. Laminar appendage of first joint of mandibular palp well developed, equal in length to two-thirds of the second segment, and its apical setæ stretching forward over the third segment. The first maxillæ are distinctly jointed at the union of the ciliated portion with the naked extremity. Caudal laminæ more than twice as broad as the length in front, the arch of the extremity, which is formed by the posterior and distal margins, surrounded by ten ungues, which gradually increase in length, the larger ungues marginally ciliated.

In the male the antennules have one recurved plumose seta on the second joint, six on the short triangular third joint, which is longer than the fourth joint on the front margin, but excessively short on the hinder margin; the large brush-like sensory organ, and the two long terminal setæ as usual. The antennæ, apparently, have only one seta on the second joint of the appendicular branch, the falcate last joint of which is equal in length to half the preceding. The terminal unguis of the mandibular palp is long and slender, equal in length to the two preceding joints; the penultimate joint has seven spines and setæ on the front margin, and a transverse group of small setæ on the face (as in *A. mariæ*). The vermiform limb has both of the apical lips serrately divided, and bears twelve spines. The ungues

of the caudal laminæ are six, and above two ringed setæ take the place of ungues, ranging with the rest.

We are unable to say in what slight respects the shell of the male differs from that of the female. Among a series of dried specimens of this species from off Valentia, Ireland, was a specimen larger than the rest, and larger than any other that we had seen of the species. On this account, supposing it at the time to be a female, it was macerated and dissected, the shell being destroyed. It was then discovered that the sex was male.

Habitat.—The Minch; Oban, 7–20 fathoms; Lamlash Bay, Arran, N.B.; Tobermory, in the Isle of Mull; off Valentia, Ireland (A. M. N.). Guernsey (late J. G. Jeffreys, in Mus. Nor.). Cumbrae (D. Robertson). North East Coast of England, 25–35 fathoms (G. S. B.). Scilly Islands; Mulroy Lough, Co. Donegal; and Lough Swilly (G. S. B., and D. R.)

Distribution.—Naples (G. W. Müller).

Fam. II.—**CYPRIDINIDÆ**, Baird, 1850.

Shell either smooth, hispid, pitted or roughly sculptured, having a deep incision in front for the protrusion of the antennæ; in front of the incision the anterior extremity is projected in rostrate or subrostrate form; infero-posteal corner often pouting, sometimes produced into a distinct process. Antennæ with secondary branch small, sometimes rudimentary in ♀, in ♂ rarely as in the other sex, but usually much larger, and formed for grasping. Mandibular foot five jointed, terminating in ungues. The following limbs maxilliform, the first furnished with three setiferous lobes and a small appendage; last joint of palp terminating in setæ and unguiform setæ. Second maxilla with setose lobes, one of which is also furnished with an overlapping series of strong teeth, and beyond this a palp, consisting of three or fewer lobes, outside which is a large semicircular setiferous, vibratory lamina. The last of these maxilliform limbs is smaller, composed of setiferous lobes, four in number when all are developed, and a subtriangular seta-margined, thin, vibratory lamina. Vermiform limb as usual in the *Myodocopa*. No branchiæ. Caudal laminæ oval or subtriangular, armed with numerous ungues.

Diagnosis of Genera by the Animal.

Mandibular palp ending in a single unguis; penultimate joint shorter than antepenultimate, ... *Nematohamma.*

Mandibular palp ending in more than one unguis, though one sometimes larger than the others; penultimate joint much longer than antepenultimate.

Upper tooth of second maxillæ narrow, falcate, denticulated on inner margin.

Masticating process at base of mandible entire, . *Cypridina.*

Masticating process at base of mandible cleft, . *Crossophorus.*

Upper tooth of second maxillæ large, triangular, smooth-edged, ... *Philomedes.*

Upper tooth of second maxillæ subquadrate, broadly truncate at the end, smooth-edged, . . . *Tetragonodon.*

Upper tooth of second maxillæ very large, oblong, with fang-like process at one end, and dentated processes at intervals on its long extremity, . *Paramekodon.*

N.B.—The animal of *Streptoleberis* unknown. For the shell see figures of the species.

Comparison of the Limbs in the Families Cypridinidæ, Rutidermatidæ, and Sarsiellidæ.

The eyes consist of a pair, usually well developed in both sexes, but larger in the males, sometimes small or absent in the females, and between these a median ocellus, in front of which is projected a tentacular organ, sometimes short and fusiform as in *Cypridina*, more commonly elongated and filiform as in *Philomedes*.

The antennules (Pl. Lv., fig. 1) consist of 5–7 joints, and are geniculated at the end of the first joint. The last joint, to which most of the terminal setæ are attached, is always very short; the proportionate length of the remaining joint varies in the different genera. At the distal end of the inner margin of the antepenultimate joint is usually attached a conspicuous sensory organ. This organ varies greatly in the different species, and affords good generic character. In *Cypridina* it is alike in the two sexes (Pl. Lv., fig. 3), and in the form of a large, closely-annulated seta, bearing rather short and stiff filaments pinnately arranged

in double file. In *Crossophorus* a similar organ is present in the two sexes (Pl. liii., fig. 2), but here it is densely filiferous. In *Philomedes* the sensory organ is absent in ♀ (Pl. lvii., fig. 12), but similar in character to that of *Crossophorus* in the ♂ (Pl. lvii., fig. 1). In *Nematohamma* ♂ it consists of a very short clavate stem (Pl. liii., fig. 12), the termination of which is closely beset with an immense number of slender filaments of extraordinary length and great flexibility, and to the clavate stem there also is attached a long, closely-annulated seta. The females of *Tetragonodon*, *Paramekodon*, *Sarsiella*, and *Rutiderma*, have no sensory appendage, its usual place being occupied by either a simple, or an annulated seta. The terminal setæ of the limb in the ♀ are ringed, and three or more are usually subequal in length. In ♂ they undergo for the most part various modification; in *Nematohamma* they are similar to those which usually occur in the other sex; and in *Crossophorus* there are also four long setæ subequal in length; but in the genera *Philomedes* and *Cypridina* two setæ are of excessive length, more especially in *Philomedes*, in which genus these long setæ are usually carried reflexed upon the limb (Pl. li., fig. 4). In *Cypridina* a further peculiar modification takes place (Pl. lx., figs. 19–21), two setæ, of much less length, are bulbously swollen at the base, and bear a flattened spine-like process to the side of which are attached one or two circular, saucer-like sucking disks; moreover, the longer setæ throw off strap-formed processes from their side, some of which processes are also furnished with sucking disks.

The antennæ (Pl. lv., fig. 4) consist of a basal joint of prodigious size, and one or two branches; the great basal joint is subcordate or pyriform, its breadth in some genera exceeding the length. To the end of this basal joint is attached the well-developed swimming branch, which consists of nine joints, the first very long, the remaining joints short, but the third in ♂ is often longer than the second. Each joint from the second to the eighth is furnished with one long, ringed, plumose swimming seta, but sometimes in the female the setæ are shorter than in the male, and sparingly setose; the last joint ends in 2–4 similar setæ. Springing from the end of the basal joint, below the origin of the swimming branch, is usually in the female a second (appendicular) branch of much smaller size, but this branch appears to be wholly absent in *Rutiderma*. In *Paramekodon* it is represented by a very large, ringed, plumose seta, near the origin of which are three very small, ringed setæ. In *Sarsiella* and *Tetragonodon* it consists of one minute papillary joint, bearing a seta. In *Cypridina* and *Philomedes* the development is greater, the organ consisting of at least two small joints furnished with setæ. In the male this branch attains usually greater development (Pl. lvii., fig. 2), and assumes the form of a grasping organ, usually three-jointed, with the last of these joints more or less curved or falcate, and capable of reflection on the penultimate joint; but in the genus *Cypridina* it does not differ from that

of the female. The absence of the grasping organ in *Cypridina* is remarkable, accompanied as it is in that genus by the presence of sucking-disks on the male antennules; and it would seem to be a reasonable conclusion that whereas in *Philomedes*, &c., the female is grasped by the prehensile organ of the antennæ, she is in the case of *Cypridina* held by the sucking-disks of the antennules.

Remarkable modifications are characteristic of the mandibular organ, the palp of which may consist of 2–4 joints. The mandible itself is often furnished with what has been called a "mandibular process." This process in the genus *Cypridina* is in the form of a small securiform, entire, setose lobe (Pl. LV., fig. 6), and is present in both sexes; in most other genera the lobe is cleft either almost to the base, or only a little way down (Pl. LIII., fig. 4). It is remarkable, if it assists in mastication, that a divided hirsute lobe of this kind is present in ♀, but not in ♂, in the genus *Philomedes*, and that in the male of this genus the masticating spines, presently to be described, are also absent, while *Crossophorus* has an exactly similar lobe present in both sexes. *Rutiderma* ♀, *Paramekodon* ♀, and *Tetragonodon* ♀, are furnished with a cleft process, but in *Sarsiella* ♀ it is altogether absent. The first joint of the palp in all cases where the basal joint is furnished with a masticating process, bears on its lower margin "masticating spines," which are of peculiar and varied structure in different genera (Pl. LIII., fig. 4 *a*). The extremity of this joint above has usually a small laminar appendage; the two final joints vary greatly, and afford good generic character. In *Cypridina* the penultimate joint is long, about equalling the two preceding joints, gradually attenuating from the base to the extremity, and densely setose above. In *Crossophorus*, *Philomedes*, and *Tetragonodon*, the joint is also long and densely setose above, but scarcely attenuated. In the preceding genera the last joint ends in several setæ and two or more ungues of moderate length. In *Paramekodon* the penultimate joint is also very long, with a dense fascicle of seta on the upper margin, and the limb terminates in a slender curved unguis of remarkable length. In *Nematohamma* and *Sarsiella* (Pl. LX., fig. 10) the penultimate joint is very short, less or not more than half the length of the preceding. In the former genus it bears only one large, annulated seta on the upper, and one similar seta on the lower margin, and the limb ends in a single large unguis, but no setæ, the unguis nearly equalling in length the last three joints. In the latter genus there are no setæ on the three terminal joints, each of which supports an unguis, which in consequence of the extreme shortness of the last joints are brought close together, each unguis being successively longer than the preceding. Lastly, *Rutiderma* possesses a limb of entirely different structure (Pl. LVIII., fig. 14); the last three joints are coalesced into a joint of extraordinary massiveness, which gives support at its extremity to a large chela, the finger

and thumb of which are very strong, forming a grasping organ, the inner edge of the lower claw being finely serrated.

The first maxillæ are furnished with three seta- or spine-tipped lateral lobes, and a terminal, usually two-jointed, palp (Pl. LIII., fig. 5). The first joint of the palp is usually of some length, the last short, bent inwards, and ending variously in setæ, spines, and ungues.

The second maxillæ are always furnished outwardly with a semi-elliptic, thin, vibratory lamina, set all round with long, plumose setæ. The limb itself attains its maximum development in *Cypridina* and *Crossophorus* (Pl. LIII., fig. 6), and consists of three small lobes fringed with spiniform setæ of varied structure, followed by a fourth lobe which, besides setæ, is armed with a series of five or six teeth, overlying each other, the uppermost being the largest. The teeth (Pl. LIII., fig. 6 *b*) are narrow, upright, slightly curved at the tip, and strongly denticulated on the inner edge. Beyond this tooth lobe a fifth may be made out, which is edged with stiff spine-like setæ, many of which are serrated at the edge. Beyond this again is a three-lobed palp, each lobe ending in setæ. In other genera several of these lobes are difficult to distinguish, or altogether absent, and the palp, though always present, is sometimes represented by only one lobe. But it is desirable to notice the teeth further, for they have every appearance of being really teeth, and often of powerful structure for use in mastication, and the exact form of these teeth is very characteristic of different genera. In *Philomedes* the outermost tooth is wide at the base, somewhat triangular, and smooth on the edge; the teeth, however, which underlie this are denticulately edged. In *Tetragonodon* (Pl. LVIII., fig. 6) the tooth is of very large size, occupying the greater part of the end of the member, subquadrate in form; broadly truncate at the end and smooth-edged. In *Paramekodon* (Pl. LIX., fig. 8) it assumes the shape of a long oblong, the long side being uppermost; at one end of this oblong rises a fang-like elevation, smooth on the edge, and at intervals beyond this the tooth-plate give out three processes, each cleft at its apex into two, three, or four points. In *Rutiderma* (Pl. LVIII., fig. 15) the tooth is trifid, with smooth edges. In *Sarsiella* there are no teeth, or even spine-like setæ, but only ordinary setæ on the limb.

The third maxillæ, when most fully developed, as in *Crossophorus* (Pl. LIII., fig. 7) and *Cypridina*, consist of four small, seta-bearing lobes, behind which is a triangular seta-edged, thin, vibratory lamina. The organ in other genera becomes more and more simplified, until in *Sarsiella* the vibratory lamina and the lobes are all represented by a single lobe.

The vermiform appendage is very constant in general character, the chief difference being found in the exact structure of the terminal lips.

Genus 1. Crossophorus, G. S. Brady.

("Report 'Challenger' Ostracoda," 1880.)

Shell in general form as in *Cypridina*, the hinder extremity in the type species very broadly rounded; texture firm and calcareous; antennules with second joint only slightly longer than the third, which on the front side is much longer than the fourth, and equal to the fifth joint, this latter in both sexes furnished with a long filiferous sensory seta; sixth joint very short; last joint in both sexes terminating in three long setæ and several shorter ones. Antennæ have the appendicular branch in ♀ three-jointed, the last joint terminating in a long seta, and in ♂ like that of *Cypridina*, of much larger size formed for grasping, the last joint falcate, and closing with the second. Mandible having a cleft, setose masticating process, and also masticating spines on the first joint of the palp; both masticating process and spines present in the two sexes. Second maxillæ have several upright teeth, curved at the apex, with denticulated edge, as in *Cypridina*. Caudal laminæ furnished with stout ungues alternating with others of much more slender and spine-like character.

This genus approaches nearest to *Philomedes*, from which it is distinguished by the proportionate length of the joints of the antennules, by their having the sensory filiferous appendage present in both sexes, and by the male having the last joint setose in the same way as in the female, instead of bearing the two remarkably long setæ characteristic of *Philomedes*. The peculiar arrangement of the armature of the caudal laminæ is unlike that of any other known genus.

Crossophorus imperator, G. S. Brady.

(Pl. liii., figs. 1–11.)

1880. *Crossophorus imperator*, . . Brady, G. S. "Report 'Challenger' Ostracoda," p. 158, pl. xxxviii., figs. 1–10.

Shell firm, porcellanous, and polished; seen from the side very broadly and regularly oval; height equal to three-fourths of the length; antennal sinus of moderate size, and expanded laterally so as to produce two obliquely-placed depressed areas on the anterior surface of the shell; rostral process curved downwards, and sharp; posterior extremity very broadly rounded; dorsal and ventral margins equally convex, not the slightest angularity on the infero-posteal portion of the shell. Seen from above the form is oblong-ovate, widest in the middle, subacuminate in front, and rounded behind; width equal to more than half

the length; end view ovate. Length of Pacific ♂ 8·4 mm. Length of Atlantic ♀ 7 mm.; height 5·8 mm.

Antennules in ♀ (fig. 2) have the second joint only slightly longer than the third, which on the front side is much longer than the fourth, and equal to the fifth; sixth and seventh very short; second joint with eight anterior, two lateral, and four posterior simple setæ; third joint with seven anterior and two posterior setæ; fourth with three distal anterior and three distal posterior setæ, this joint is considerably longer on the anterior than on the posterior margin; fifth bearing on the distal posterior extremity a long-ringed seta, beset on all sides with sensory filaments; sixth with one long and one small ringed seta; last joint with two long, and four short ringed setæ of varied form; the three longest setæ (one on penultimate and two on last joint) have long cilia here and there as usual in these setæ. Antennæ having the swimming branch furnished with twelve setæ, the last joint being very broad and bearing five of these setæ; a spine at the base of each seta; the lowest seta is short, but not spinose on the edge; the appendicular branch (fig. 3) in ♀ of similar character to that of *Cypridina*, consisting of a short, basal joint which has about five small setæ, a second much longer joint with one distal seta, a third which tapers to a point as a long, slender, ringed seta.

Mandibular limb (fig. 4), furnished at the base with a cleft, hirsute process, similar to that in the genus *Philomedes*, present in both sexes; at the base of the first joint of the palp are two spines which have five or six spinules on the upper part of one side (fig. 4 *a*); there are also six setæ on the distal portion of the front margin, whence also springs a bisetose appendage, which extends beyond the short following joint, on the hinder margin is also a single, greatly developed, ringed and ciliated seta, which equals in length the whole of the rest of the limb; second joint of palp very short, fully twice as wide as long, hinder margin with a fascicle of six setæ of various lengths, some of which are ringed and ciliated; third joint of equal width throughout, and three times as long as wide, front margin densely clothed with setæ, hinder margin with a group of about six setæ at the extremity; last joint terminating in two, long, equal nails, and two or three small setæ. The four succeeding limbs bear a close general resemblance to the same organs in *Cypridina*. The first (fig. 5) has three lateral lobes wider than usual, and over-lapping each other, each furnished with many terminal setæ; the palp is three-jointed, with one seta at the end of the first, and two at the second joint; last joint broad at the extremity, ending in several ungues and setæ; second maxillæ (fig. 6), having the tooth-lobe furnished with very strong falcate teeth (fig. 6 *b*), graduated in length from the largest and uppermost to that which is most deeply seated; the teeth are denticulated on the inner face; vibratory lamina with more than ninety marginal setæ.

The vermiform last limb is small; at the extremity one lip is in the form of a blunt tooth (fig. 8); the other is divided into several (six?) finger-like curved processes, which are ciliated on the edges; the spines are numerous (twenty counted), scattered for some distances along the limb; at their extremities (fig. 9) they bear two or three pairs of spinules, and the extremity is drawn out to a long and very fine termination beyond the last pair of spinules. Caudal laminæ (fig. 10) with seven chief ungues, which are crenated on the edge, and thirteen others of much more slender form; the arrangement of these is unusual; commencing from the base, we find first six slender seta-like ungues, then a distinctly larger one (the first and much the smallest of the seven large ungues, the six following gradually increasing in length) followed by a setiform unguis, then a large unguis, setiform unguis, large unguis, two setiform ungues the posterior the larger, large unguis, two setiform as before, large unguis, two setiform as before, and then two terminal large ungues, of which the penultimate is the longer.

Habitat.—The type specimen, a male, was dredged by the "Challenger" Expedition, Stat., 168, which is a little to the East of New Zealand, lat. 40° 28′ S.; long. 177° 43′ E., in 1100 fathoms, bottom temperature, 2° o. C.; bottom, gray ooze. The second specimen, from which the animal is here described, and the drawing made is a female, which apparently differs in no respect from the male except in sex, was procured by the "Porcupine" Expedition of 1869, in the Atlantic, west of Donegal Bay, Ireland, Stat. 20, lat. 55° 11′ N., long. 11° 31′ W., in 1443 fathoms, bottom temperature 37° Fahr. It is interesting to observe, that though the two specimens were found so very far apart, the temperature of the water only differed by $1\frac{1}{2}$ degree, since 2° C. equals 35·6 Fahr.

Genus 2. Cypridina, H. Milne-Edwards, 1838.

In Lamarck, "Hist. des Anim. sans verteb.," vol. v., p. 178 (including sub-genus *Pyrocypris*, W. Müller).

Shell, ventricose, never sculptured, oval; only slightly differing in the sexes; antennal sinus opening downwards, overhung in front by the rostrate process, which bends downwards; sinus much contracted by a thin lamina—an extension of the inner margin of the shell—which surrounds it; the hinder extremity may be angled, or have the antero-posteal corner with or without pouting lips.

Eyes well developed. Frontal tentacle short, usually fusiform. Antennules (Pl. LV., fig. 1) seven-jointed, in both sexes furnished with a large sensory organ at the hinder extremity of the antepenultimate joint, but of entirely different form in the two sexes; last joint ending in many setæ, of which three are primary; in the male (Pl. LX., figs. 19–21) two of the setæ possess basal

appendages which are bulbously swollen at the point of origin and above form a somewhat sword-shaped, flattened and acutely-pointed spine, the face of which has an angulated prominence near the apex, and towards the base a saucer-shaped sucking disk; the setæ themselves are also furnished at intervals with slender lateral filaments, some of which give support to several saucer-shaped sucking disks of similar character to, but very much smaller than those of the basal processes. Antennæ (Pl. LV., fig. 4), with the third joint not longer than the second in both sexes, the appendicular branch is also alike in the sexes, small, three-jointed, and terminating in a straight seta. The mandibular foot (Pl. LV., fig. 6) has a securiform, hirsute, undivided masticating process on the basal joint, and present in both sexes; no forked spines on the first joint of the palp, to the end of which joint is attached above a short lobe usually ending in two setæ; the penultimate joint is long and slender, gradually narrower towards the extremity, its upper margin densely ciliated; last joint very short, ending in three nails. The first maxillæ (Pl. LV., fig. 7) have three setiferous lobes at the base; to the end of the ante-penultimate joint is attached another lobe bearing three setæ; the penultimate joint is very broad, and as long as the preceding portion of the limb; the last joint is very short, and terminates in many spines and setæ of varied character. The second maxillæ (Pl. LV., fig. 8) have four (or five?) lobes margined with variously formed setæ; the penultimate of these lobes is the chief masticating organ, having six upright, somewhat falciform teeth graduated in length from the outermost to the innermost, and all denticulately cut on their inner edge; the outer lobe bears stout setæ, which are pectinated on one side; beyond these lobes, is a palp divided into three portions, the central being the wider, furnished with several setæ, while the inner ends in three, and the outer in two setæ; beyond is a large semicircular seta-edged, vibratory lamina. The penultimate limb (Pl. LV., fig. 9) has three (four?) setiferous lobes, and outside of these a sub-triangular seta-edged vibratory lamina. The last vermiform, ringed limb (Pl. LV., fig. 10) is furnished with numerous spines, which are as usual spinulated at their extremities. The caudal laminæ (Pl. LV., fig. 11) are of the usual structure of *Myodocopa*.

1. Cypridina norvegica, Baird.

(Pl. LIV., figs. 7, 8; Pl. LX., figs. 19–21.)

1860. *Cypridina norvegica*, . . BAIRD, "On some New Species of *Cypridina*," Ann. & Mag. Nat. Hist., vol. vi., p. 139.

1860. ,, ,, . . BAIRD, "Note on the Genus *Cypridina*, with a Description of some New Species," Proc. Zool. Soc., p. 200, pl. lxxi., figs. 4, 4*a*–*d*.

1865. ,, ,, . . SARS, G. O., "Oversigt af Norges marine Ostracoda," Vid.-Selsk. Forhand., p. 104 (separate copy).

1869. ,, ,, . . NORMAN, "Last Report Dredging Shetland Isles," Rep. Brit. Assoc., 1868, p. 295.

Shell of female seen from the side subovate, greatest height central, extremities nearly equal, ventral and dorsal margins moderately and equally arcuated; hinder margin centrally slightly truncate or a little emarginate, infero-posteal corner completely rounded; anterior extremity, with the antennal sinus central, very narrow and shallow, directed obliquely upwards, the rostrate process small, well arched above (in continuation with the dorsal margin), acute at the extremity, and pointing slightly downwards, the junction of the lower side of the sinus with the ventral margin forming nearly a right angle, though the angle itself is rounded off; valves white, smooth, shining, and sub-transparent. Seen from above the form is elongated-ovate, the ends nearly equal, the anterior slightly more pointed; greatest width central, equal to half the length. Length 4 mm.; height 3 mm.

In the female the antennules are seven-jointed, the first two joints sub-equal in length, without any setæ; the third is very short, with two setæ; the fourth about twice as long as the third, with two distal setæ; the fifth somewhat shorter than the third, its outer margin naked, the inner furnished at its extremity with a long, ringed, filiferous, sensory appendage; last two joints very short, bearing five or six short setæ and three long setæ, on which are solitary cilia at regular intervals. Antennæ with swimming branch bearing eleven swimming setæ, each with a spine by its base, the lowest seta short, not plumose but spined on the proximal margin, the most distal seta very minute; appendicular branch having the first short joint with three setæ, the second longer, with a distal seta; third tapering and terminating in a very long, tapering, and ultimately very fine seta.

The mandibular limb is furnished at the base with a hirsute masticating lobe, which is not cleft; first joint of palp having one seta about the middle of the front margin, a pair of longer setæ further on, and at the extremity a single-joint laminar appendage, which is as long as the second joint and bears two setæ, the hinder margin has three setæ, and a greatly developed, ringed and filiferous sensory seta, which is longer than the whole of the rest of the limb; second joint very short, triangular, no setæ on front margin, on the hinder a fascicle of three, of which one is ciliated; third joint equal in length to the two preceding, narrow and gradually tapering distally, front margin densely setose, except the distal third, hinder margin with only three small setæ, two of which are at the extremity; last joint scarcely separable from the preceding, ending with two chief ungues, and two of smaller size.

The first maxillæ bear three lateral lobes, which partially overlie each other and end in setæ of varied form, but most of them of spine-like character, and densely ciliated; there is also a laminar appendage directed forwards, and furnished at the base with a downward-pointing lobe and ending in two setæ, a third on the front margin; the joints of the palp (which is incurved at the extremity) are furnished with numerous spines and setæ of varied structure, some of the largest being pectinated on one side. The second maxillæ end in five lobes, three of which are lateral and two terminal; they are fringed with variously-formed setæ, those of the last lobe being for the most part strongly pectinated on one side; the penultimate lobe is armed with a graduated series of six narrow, upright teeth,* strongly denticulated on the inner margin, and curved at the extremity; beyond the last lobe, already described, is a three-lobed palp, the middle lobe the widest, ending in five setæ; the others are narrow, the lowest has three setæ, one of which is lateral and the others distal, the furthest with two distal setæ; to the outer side of the limb is attached a large semicircular thin vibratory lamina, edged all round with long plumose setæ. The penultimate limbs or third maxillæ end in three setiferous lobes, the outer side of the limb carries a sub-triangular vibratory lamina, margined at first with nine plumose setæ, beyond which the margin is simply finely ciliated, while near the further angle are three more plumose setæ.

The vermiform limb bears very numerous spines, of which there are more than twenty at the end, and 9–13 on each side, each furnished with 5–6 pairs of distal spinules. Caudal lamina armed with nine ungues, which gradually increase in length from the first to the last, and are all finely ciliated on the edge.

The male is rather smaller than the female, the general form including that of the rostrate process is as in the latter sex, but the hinder extremity differs slightly,

* These are so buried among the setæ that they are difficult to detect, and it requires an object-glass of one-eighth to make them all out clearly, though the two upper and larger may be easily seen.

the supero-posteal corner is less abruptly rounded and more sloped away, and the infero-posteal portion is slightly produced in lip-like form. The eyes are considerably larger than in the female. The antennules terminate in four long primary setæ (Pl. LX., fig. 19), though very generally one or more of these have been broken off near the base, and exhibit signs of reproduction; the lowest setæ and the second from above exhibit marked characteristics; they are bulbously swoollen at the base, and from this bulb is given off a lobe with acute termination; to the side of this lobe is attached a remarkable saucer-shaped organ (fig. 20) of considerable size, and above a second in a rudimentary state; the setæ themselves at varied intervals send out lateral long processes which run side by side with the setæ at first, but ultimately diverge; two or three of these processes (fig. 21) are furnished at their extremity with saucer-shaped organs, usually five in number, of similar character to that of the basal lobe, but very much smaller.

What purpose do these remarkable organs serve? Their form, and the circumstance that the setæ which bear them are so frequently broken off would seem to favour the view that they are sucking disks used in grasping the female. On the other hand it is possible that their function may be similar to that of the calceolæ which are so frequently characteristic of the antennules and antennæ in the males of the amphipoda. The antennæ in all respects resemble those of the female. The copulatory apparatus consists of two ovate lobes.

Habitat.—Only a single specimen of this species is known from British seas; it was dredged by A. M. N. off the Unst Haaf, Shetland, in 1867.

Distribution.—Kloster Fjord and Stoksund, both in the Hardanger Fjord, 100–126 fathoms; Florö; Trondhjem Fjord, 150–300 fathoms (A. M. N.). Lofoten Islands, 300 fathoms (G. O. Sars). The type specimen was also dredged on the coast of Norway by the late R. M'Andrew.

2. **Cypridina megalops** (G. O. Sars).

(Pl. LIV., figs. 5, 6.)

1871. *Cypridina megalops*, . Sars, G. O., "Undersögelser Hardangerfjordens Fauna 1. Crustacea," Vidensk.-Selsk. Forhand, p. 278.

Female, very like *C. norvegica*, but not so large, shorter and higher in proportion, the greatest height, instead of being central, is a little behind the middle, and the shell is higher behind than in front*; ventral margin equally arched throughout; dorsal moderately convex in the centre, less so in front, and more so

* In *C. norvegica* ♀ the two ends are of sub-equal height, and in the ♂ of that species the anterio portion is higher than the posterior.

behind; hinder margin obtusely, and rather obliquely, truncate, the supero-posteal portion completely rounded off, infero-posteal portion the most produced, but without any sign of angularity; rostrate process as in *C. norvegica*, but projected further forward over the antennal sinus; lower margin of that sinus arcuate from the base, and at the same time sloping slightly backwards, as it unites in a bold curve with this ventral margin; valves white, pellucid, glabrous (or nearly so), and shining; seen from above the form is elongated-ovate, greatest breadth central, and equal to half the length; length, 2·3 mm.; breadth, 2 mm. The eye is very large; "the appendicular branch of the antennæ is very short, nodiform, ending in a long seta; the penultimate joint of the mandibular palp is very narrow; the third pair of following limbs has the vibratory lamina margined with fourteen ciliated setæ, the five posterior of which are separated from the preceding by a short interval; caudal laminæ of usual form furnished with eleven finely-toothed ungues."

Very rare at Utne, in the Hardanger Fjord, in 40–50 fathoms (G. O. Sars). The shell has been described from a specimen kindly sent to us by Professor Sars.

3. Cypridina mediterranea.

(Pl. liv., figs. 1, 2 (typica), figs. 3, 4 (Var. *b*); Pl. lv., figs. 1–11 (typica).

1845(?). *Cypridina Edwardsii* in text, *C. mediterranea* on plate. O. G. Costa, "Fauna del Regno di Napoli.," pl. iv., figs. 1–14.

1865. *Cypridina messinensis*, . . Claus, C., "Ueber der Organisation der Cypriniden," Zeitsch. f. wiss. Zool., vol. xv., p. 143, pl. x., figs. 1–7.

1871. *Bradycinetus Brenda*, ♂ . Brady, G. S. (*nec auct*) "Review *Cypridinidæ* of European Seas," Proc. Zool. Soc., p. 292, pl. xxvi., fig. 6.

1875. *Cypridina mediterranea*, . Claus, C., "Neue Beobach. ü. *Cypridinen*," Zeits. f. wiss. Zool., vol. xxiii., p. 221, pl. xi., figs. 16′–20.

1876. ,, ,, . . Claus, C., "Unters. z. Erforschung der genealogischen Grundlage des Crustaceen-System.," pl. xviii., figs. 4–6, ♂, ♀.

1884. ,, ,, . . Claus, C., "Elementary Text-book of Zoology" (Sedgwick's translation), vol. i., p. 425, woodcuts, ♂, ♀.

1887. *Cypridina mediterranea*, . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna. iv. *Ostracoda mediterranea*," p. 36, pl. ii., figs. 3–5; pl. vii.; pl. viii., figs. 1–5.

1894. ,, ,, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 206, pl. ii., figs. 1, 2, 4, 5, 8–20, 22–26, 33.

We are not sure what the right name of this species should be. Authors have called it *C. mediterranea*; but Costa, in the text of the "Fauna del Regno di Napoli" names it *Cypridina Edwardsii*, but in description of plate *C. mediterranea*. As far therefore as that work is concerned it should bear the former of these two names. But this was probably the species described in an earlier paper by Costa,* which neither we ourselves, nor apparently other authors, have seen, and as the name ultimately adopted must depend on that used in the paper referred to, we here follow other authors in the use of *C. mediterranea*.

Shell of female regularly oval, greatest height central, extremities diminishing in height equally; ventral and dorsal margins equally and evenly arcuate throughout, hinder extremity with the upper portion formed by the continued equal sweep of the dorsal margin, lower portion pouting slightly in lip-like manner, but no angularity anywhere; rostral process, as in the two preceding species; antennal sinus opening obliquely downwards and forwards, lower margin arching, with continued sweep, from the bottom of the sinus to unite, without angularity, with the ventral margin—this description applies to the shell itself, not to the thin lamina, which, springing from its inner side, surrounds and contracts, as usual, the antennal sinus; valves glabrous, less strong than in the preceding species, but Sars says: "Interdum valde calcareæ et opacæ." Seen from above the form is regularly ovate, the greatest width central, and thence tapering evenly to the extremities, which are sub-equal. Length, 2·9 mm.; height, 2 mm. The eyes are rather large. The sensory appendage of the fifth joint of the antennules (Pl. lv., fig. 3) has the filaments pinnately arranged in two lines, and few in number (about ten). The small branch of the antennæ is of the same general form as in *C. norvegica*, but much smaller, its joints very short, but the terminal seta is of considerable length; the swimming setæ of the swimming branch are eleven in number, there is a spine by the base of each of the larger ones (Pl. lv., fig. 5), and the first setæ is not plumose, but spined on one side. The vibratory lamina of the penultimate limbs is triangular (Pl. lv., fig. 9), with the marginal setæ uninterruptedly

* O. G. Costa, "Illustrazioni al genere Cypridina e descrizione di una novella specie Dona della Accad. Pontaniana agli Scienz. Ital.," p. 57.

surrounding the outer edge. The caudal laminæ are furnished with eleven ungues (Pl. LV., fig. 11), edges of the larger ungues crenated, of the smaller ciliated.

The shell in the male very closely resembles that of the female in form, but the labiate projection of the infero-posteal portion is more pronounced, and the whole form rather more elongated. The eyes are larger than in the female. The antennules have the sensory appendage of fifth joint similar to that of the female, and bear at their extremity two long (not reflexed) setæ, and also two two setæ which are bulbously swollen at the base, from which rises an acutely pointed spine-like process which gives attachment on the inner side to a saucer-shaped appendage: from these setæ arise also long lateral processes, some of which support saucer-shaped organs, usually three in number. The appendicular branch of the antennæ is similar to that of the female.

There are, apparently, two forms of this species—(*a*) That here described, which is the *C. messinensis*, and, subsequently, the *C. mediterranea* of Claus, and the *C. mediterranea* of Sars, of which the ♀ is figured by us (Pl. LIV., figs. 3, 4). This form we have from Naples (A. M. N.), and the Adriatic (Prof. Heller, in Mus. Nor.), Messina (Claus); (*b*) a form in which the shell is much less high in proportion to the length, and regularly ovate (3 mm.), with the hinder extremity regularly rounded, the greatest projection central (and no infero-posteal pouting lips). When examining the shells only we came to the conclusion that this was a distinct species, but a close comparison of the animals of the two forms showed them to be exactly alike, and therefore we do not separate them. This form is figured by us (Pl. LIV., figs. 1, 2). It was procured by us (A. M. N.) when at Naples Zool. Stat. in 1887, and appeared to be much more abundant there than form (*a*).

Now, this latter form (*b*) closely agrees with Costa's figure of *C.* (*Edwardsii*) *mediterranea*, which shows no infero-posteal labiate projection, and if it should prove distinct from form (*a*), must bear Costa's name. Meanwhile, we would call this form (*b*) *C. mediterranea* (Costa), and form (*a*) *C. mediterranea var. messinensis* (Claus). [G. W. Müller has since this was written described form *a* under the name *Cypridina squamosa*.]

4. **Cypridina angulata**, G. O. Sars.

1887. *Cypridina angulata*, . . Sars, G. O., "Nye Bidrag til Kunds. om Middelh. Invertebratfauna: iv. Ostracoda mediterranea," p. 43, pl. iii., figs. 1, 2; pl. viii., figs. 6, 7.

"Shell of female, seen from the side, rounded-oval; dorsal and ventral margins regularly arcuate, equally high at the two extremities; hinder margin

exserted below the middle, and there forming a distinct and prominent angle; rostrate projection moderately prominent, sub-truncated in front, with a distinct angle below, but not above; eyes very large; limbs little differing from those of *C. mediterranea*, length 2·62 mm."

Two females taken by Prof. G. O. Sars, at Messina, Sicily, in 10–20 fathoms

We have not seen this species.

Genus 3. Philomedes, Lilljeborg, 1853.

(= Cypridina, Lilljeborg, ♀ 1853, = Philomedes, Lilljeborg, ♂ 1853,
= Bradycinetus, G. O. Sars, ♀ 1865.)

Shell of female more or less ovate, either smooth, hispid, or highly calcareous, and sculptured with pittings or ribs; antennal sinus usually opening downwards; rostral process obtusely terminated, overhanging the sinus; infero-posteal angle often angularly produced. In the male the shell is longer in proportion to the height, and the antennal sinus is of different form, being widely open forwards, as well as downwards, because the rostral process is here truncated anteriorly, and rises almost at a right angle from the bottom of the antennal sinus, which it does not overhang; in rugose forms, the valves also of the male are much less sculptured than in the female.

Eyes of ♀ small or wanting, of ♂ well developed. Frontal tentacle long and slender. Antennules six-jointed (Pl. lvii., fig. 12; fourth joint without any sensory organ in ♀, but in ♂ (Pl. lvii., fig. 1) with such an organ, which consists of a large annulated appendage beset with numerous filaments, extremity of the limb ending in ♀ in several subequal setæ, in ♂ two setæ are immensely developed, of very great length, and usually carried reflexed upon the limb. Antennæ with appendicular branch small in ♀ (Pl. lvii., fig. 13), but in ♂ (Pl. lvii., fig. 2) much larger and prehensile, the last joint closing on the second. Mandible of ♀ having the basal joint furnished with a masticating process which is cleft at the apex (Pl. lvii., fig. 14); first joint of palp, with peculiar formed masticating spines at the base, and furnished at the dorsal extremity with a small appendage; third joint only slightly narrowing to the extremity, last joint terminating in ungues, the ♂ is wholly destitute of the masticating process and masticating spines (Pl. lvii., fig. 3). Most of the remaining limbs and the caudal laminæ are not markedly different from those of *Cypridina*. The second maxilla, however, differ considerably in minute detail; in the female there are only four lobes, the place of the outermost lobe being occupied by a series of teeth, the uppermost of which is large and triangular, and not denticulate on the margin; beyond the tooth the group of the spine-formed setæ, and other setæ characteristic

of *Cypridina* are absent and the palp consists of only two lobes, the hindermost lobe in *Cypridina* being absent and represented here by two setæ on the limb itself. The penultimate appendages have only three lobes (Pl. lvii., fig. 6), the first lobe in *Cypridina* being in this genus absent, but represented by two setæ on the member itself ; the vibratory lamina as in *Cypridina*.

1. **Philomedes brenda** (Baird).

(Pl. li., figs. 1–3 ; Pl. lvi., figs. 1–3.)

1850. *Cypridina brenda*, . . . Baird, "Nat. Hist. Brit. Entom.," p. 181, pl. xxiii., figs. 1 *a–g*, ♀ .

1853. *Cypridina globosa*, . . . Lilljeborg, "De Crust. ex. ord. tribus, &c.," p. 171, pl. xvii., figs. 2–10 ; pl. xviii., figs. 1–3, 7, ♀ .

1853. *Philomedes longicornis*, . Lilljeborg, "De Crust. ex ord. tribus, &c.," p. 176, pl. xxvi., figs. 4, 5, 6, 14, 15, 16, ♂ .

1855. *Asterope grœnlandica*, . . Fischer, S., "Beitrag. zur. Kenntniss der Ostracoden," 1855, p. 26, pl. ii., figs. 26–34, ♀ .

1865. *Bradycinetus globosus*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," Vid.-Selsk., Forhand., p. 110, ♀ .

1865. *Philomedes longicornis*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," Vid.-Selsk. Forhand, p. 106, ♂.

1868. *Bradycinetus brenda*, . . Brady, G. S., "Mon. Recent Brit. Ostracoda," Trans. Linn. Soc., vol. xxvi., p. 466 ; pl. xxxiii., figs. 1–5 ; pl. xli., fig. 5, ♀ .

1869. *Philomedes globosus*, . . Sars, G. O., "Undersögelser over Christianiafjordens Dybvandsfauna," 1869, p. 51, ♀ , ♂ .

1876. *Bradycinetus brenda*, . . Norman, "Biology 'Valorous' Cruise, 1875," Proc. Roy. Soc., vol. xxv., p. 206 (no description).

1891. *Philomedes brenda*, . . Norman, "Crustacea Ostracoda of Norway," Ann. & Mag. Nat. Hist., ser. 6, vol. vi., p. 119.

[Not *Bradycinetus brenda*, . . Brady, G. S., "Review of Cypridinidæ of European Seas," Proc. Zool. Soc., 1871, p. 292, pl. xxvi., fig. 6.]

Shell of female broadly ovate, greatest height central, equal to three-fourths of the length ; ventral margin boldly and regularly arched ; dorsal margin

slightly arcuate, descending suddenly in front; posterior margin rather obliquely truncate, with an angle at the junction with the ventral margin; anterior margin highly vaulted, from the summit of the vault an oblique truncation descends to form the rostrate process, which is very broad, and angled at the extremity; it overhangs the moderately deep sinus, which is distinctly inferior, and widely open, and has its lower margin nearly straight, and uniting with the ventral margin in an obtuse angle. Surface of valves everywhere pubescent, with short erect hairs. Seen from above the form is elongo-ovate, the sides evenly arched, the greatest breadth central, and equal to half the length. Length of Greenland specimens 3 mm., height 2 mm. Scandinavian and British specimens slightly less. Colour pale yellow. The antennæ in the ♀ have the tactile seta of the small branch of considerable length, and the terminal spine hook-shaped, curved, and forming a prehensile organ with the flattened joint from which it springs. The masticatory process of the mandible is very deeply divided, and the masticatory spines are furnished with a single stout lateral prong. Vibratory lamina of the penultimate limbs narrowly triangular, and edged with about fifteen setæ. The vermiform last limb (Pl. LI., figs. 2, 3) is furnished with more numerous spines than usual, of which about sixteen are at the extremity, and eleven on the sides; the distal portion of the spines is furnished with 7–8 serrations on each side. Ungues of the cauda about eighteen; the two ultimate pairs have strongly spined edges, the rest are not spined but ciliated; in the male the spinose and ciliated garniture of the ungues is more delicate than in the female.

The male has the shell of very different form than that of the female; the outline is more oblong, the height about three-fifths of the length; both ventral and dorsal margins are only slightly arcuate; the posterior extremity is rather obliquely truncated, as in the female, but the infero-posteal corner is well rounded, and devoid of the angularity of the other sex; the anterior sinus is very shallow, but widely open, the highly-vaulted anterior extremity rising perpendicularly from the bottom of the sinus thence arches backwards, so that the overhanging portion, characteristic of the female, is quite obsolete. The surface of the valves has, in addition to the pilose investiture, longer setæ sparsely distributed over the posterior portion. The grasping branch of the antennæ of the male (Pl. LI., fig. 1) has the second joint slightly curved backwards, and furnished with three closely-ringed flagella on the inner margin, the third joint is formed for reflection on the second, and arcuate in a reverse way to the latter, on which it closes; the inner face smooth, furnished with one closely-ringed flagellum near the base, and a minute seta at the tip.

Habitat.—Off the coast of Durham, near the Dogger Bank, 1862 (A. M. N.). "Off Noss, in Shetland, 80–90 fathoms" (M'Andrew).

Distribution.—Holsteinbourg Harbour, Greenland ("Valarous," 1875); Dröbak, Christiania Fjord, 30–100 fathoms; Bog Fjord, East Finmark, in great abundance, 1890; Trondhjem, 20–100 fathoms, 1892 (A. M. N.). Bergen (Lilljeborg, in Mus. Nor.). Tromsö (J. S. Schneider, in Mus. Nor.). Utne, Hardanger Fjord, 15–20 fathoms (G. O. Sars). Kullaberg, Sweden (Lilljeborg).

2. **Philomedes interpuncta**, Baird.

(Pl. lvi., figs. 6–10; Pl. lvii.)

1850. *Cypridina interpuncta*, . . Baird, "Proc. Zool. Soc.," p. 257, pl. xvii., figs. 5–10.

1861. *Philomedes longicornis*, . Norman, "Ann. & Mag. Nat. Hist.," ser. 3, vol. viii., p. 280, pl. xiv., fig. 11 (nec *Philomedes longicornis*, Lilljeborg).

1868. *Philomedes interpuncta*, . Brady, G. S., "Mon. Recent Brit. Ostracoda," Trans. Linn. Soc., vol. xxvi., p. 463, pl. xxxiii., figs. 10–13; pl. xli., fig. 3 *a–f*, ♂.

1871. „ „ . . Brady, "Review of Cypridinidæ of European Seas," Proc. Zool. Soc., p. 293, Pl. xxvi., figs. 1–5, ♀.

1894. „ „ . . Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 210, pl. iii., figs. 1, 2, 5–16, 19, 20, 24–28, 38–44.

Shell of female sub-ovate, greatest height central, equal to about five-sevenths of the length; ventral margin well and evenly arched; dorsal margin nearly straight in the middle, in front well arching to the anterior extremity, behind suddenly deflexed to the hinder margin; hinder margin obliquely truncate, furnished with a spine process at the infero-posteal corner, which is directed backwards, and a second similar spine process at the supero-posteal corner, which is directed downwards (these spines are sometimes obsolete or rudimentary). Anterior extremity, with the rostrate portion nearly erect, the upper margin of the sinus being straight, and directed with a slight obliquity downwards; the sinus itself is thus widely open, shallow, and widely rounded at its junction with the ventral margin: surface of valves altogether devoid of any pilose covering, but when in good state elegantly reticulated, the reticulations irregularly hexagonal; in the older shells this reticulation becomes more and more indistinct, and the surface is (from many localities) curiously eroded, the erosions forming circular or irregular pittings. Viewed dorsally the form is elongated ovate, the

greatest width central, and equal to half the length; anterior extremity narrowly rounded; the posterior somewhat apiculate. Length, 1·4 mm.; height, ·8 mm. It will be observed that this is a very much smaller species than the last.

Shell of male longer and more ovate than that of the female, height rather more than half the length; both ventral and dorsal margins only gently arched, the latter nearly straight in its central portion; posterior rather obliquely truncate, as in the female, but the upper spine process usually absent, the lower usually present; rostrate anterior extremity even more erect than in the other sex, its lower margin, as well as the sinus, fringed with rather long cilia.

Antennæ of ♀ (Pl. LVII., fig. 13), with the swimming setæ much shorter than in the male. Antennæ of ♂ (figs. 2, 2 *a*), having, as usual, the third joint of the swimming branch much longer than the second; the swimming setæ eleven. The short seta, arising from the apex of the second joint, is peculiar in having its external margin armed with about ten small spines; appendicular branch with two setæ on the inner margin of the second joint; last joint very protuberant at the base, then suddenly and deeply incised; this constricted portion is succeeded by another protuberance, after which the joint slopes away in cylindrical form to the end, the cylindrical portion has usually about four minute tubercles on the edge, and there is a cilium near the extremity. In the female the appendicular branch of the antennæ has three or four small setæ on the basal joint; a long plumose seta on a second joint, and a distant slender seta on the last. Mandible in ♀ (fig. 14), having the basal forked process deeply cleft, and the masticating spines with only small cilia on the side, and no prong. Vermiform appendage (fig. 7) with very few setæ, usually six terminal and four lateral. Caudal plates narrow (fig. 8), with about eleven ungues on each; the five upper ungues are very small, the sixth about twice as long, the seventh again very small, the eighth is considerably larger and stronger than the sixth, and is followed by two terminal ungues, which are very much longer and more robust than any of the preceding.

Habitat.—Plymouth, 1858; off Northumberland, 1862; Shetland, 1863; Oban and Tobermory; Valentia, Ireland, 1870 (A. M. N.). Cumbrae, Firth of Clyde; Loch Long (D. Robertson).

Distribution.—Fosse de Cap Breton, S. W. France (Marquis de Folin).

3. **Philomedes Lilljeborgii** (G. O. Sars).

(Pl. li., figs. 4–6; Pl. lii., figs. 3, 4.)

1865. *Bradycinetus Lilljeborgii*, Sars, G. O., "Oversigt af Norges marine Ostracoder," Vid.-Selsk. Forhand, p. 112 (separate copy).

Shell of ♀ roundedly-quadrangular, greatest height central, equal to nearly three-fourths of the length; ventral margin well, but not boldly, arched; dorsal margin nearly straight in the central portion, in front boldly arching to the rostrate extremity; hinder margin abruptly, and somewhat obliquely truncate, the infero-posteal corner produced into a much compressed and backward-directed point, anterior margin formed by the continuous sweep of the dorsal, until abruptly cut off by the almost horizontal face of the rostrate process, which is broad; antennal sinus inferior, moderately open, well-rounded at its junction with the ventral margin. Seen from above ovate, with a mucro behind, caused by the infero-posteal produced angle; greatest width central, equal to half the length, sides evenly arched. Surface of valves everywhere finely punctate, not setose, though the ventral margin is fringed with fine cilia, which attain much greater length on the margins of the antennal sinus, and front of the rostrate process. Length, 2·6 mm.; height, 1·8 mm.

The male differs from ♀ in a similar manner to that of *P. brenda*, the form being more oblong (Pl. li., fig. 4), ventral and dorsal margins nearly straight centrally, the latter slightly emarginate; the inferior portion of the rostrate process is, as it were, cut off, the horizontal front being thrown back as far as the bottom of the sinus, which is thus widely open, and affords ample scope for the play of the large antennules; greatest height, half the length. There is a projection at the infero-posteal corner similar to that of the female, but not so strongly pronounced.

In ♀ the antennules have the second joint about equal in length to the rest of the limb. The appendage of the antennæ (fig. 6) has one seta on the first joint, and three (of which that nearest the base is long and plumose), besides the terminal hook-formed seta on the second. The forked process and masticatory spines of this sex are as in *P. brenda*. Vermiform last limbs with few, 10–12, spines. The caudal laminæ have 9–11 ungues, which gradually increase in length and size, and are strongly denticulate on the edge.

In the ♂ the antennæ have the third joint of the swimming branch, as usual, longer than the second, and there are eleven natatory setæ, the two distal of

which are very small; the appendicular branch (fig. 5) has the second joint furnished with three comparatively short setæ, the last joint has no incision; the inner face is waved, so that the diameter is greatest just before the middle, while the extremity is also wider than the part preceding. The nine ungues of the abdominal plates are ciliated, not spined on the edge as in the other sex.

Philomedes Lilljeborgii occurs not uncommonly in the Fjords of Norway, where it inhabits deeper water than *P. brenda*. Near Drobak, in the Christiania Fjord, 100 fathoms; Bergen Fjord, south of Bukken, 150–200 fathoms; in the Hardanger Fjord, off Lervig, 150–180 fathoms and in Stoksund, 126 fathoms; Trondhjeim Fjord, 100–300 fathoms (A. M. N.) Sars's type specimens were from the first of the localities just enumerated, and he has also taken it at the Lofoten Islands. We have also specimens taken, during the second cruise of the "Porcupine," in a depth of 430 fathoms, lat. 48° 50′ N., long. 11° 9′ W.; and during the first cruise in lat. 46° 13′ N.; long. 14° 18′ W., depth 420 fathoms; for these specimens we have to thank our friend, Mr. E. C. Davison, R.N. (G.S.B.).

4. **Philomedes foveolata** (G. W. Müller).

(Pl. LVI., figs. 4, 5.)

1894. *Pseudophilomedes foveolata*, MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel. und der angrenzenden Meeres-Abschnitte," p. 212, Pl. iii., figs. 34, 35, 45–49, 51, 53, 54; Pl. iv., figs. 1, 2, 7.

Shell of the male ovate, truncated behind, greatest height central, equal to two-thirds of the length, ventral margin evenly and moderately arched throughout; dorsal regularly arched through its entire length; hinder extremity abruptly and scarcely obliquely truncated, infero-posteal corner angled, but not produced; anterior extremity vaulted; rostrate process rising obliquely forwards, its extremity blunt, and widely rounded; antennal sinus facing downwards, not wide, the lower side arcuately joining the ventral margin without any angularity; surface of valves everywhere pitted with conspicuous round foveolæ. Viewed from above it is of nearly equal breadth throughout its central portion, the sides being straight and nearly parallel, breadth not quite equal to half the height, anteriorly suddenly narrowed at the region of the rostrate process; posterior extremity broadly rounded; length, 1·6 mm.; height, 1 mm.

The antennules have the first joint naked, second longer than the first, and also longer than the remainder of the limb, with one seta on each margin, and

one on the side near the extremity; third joint sub-triangular, a single seta on each margin; fourth with two distal setæ on inner, and four and the sensory organ on the outer margin, the sensory seta long-ringed, the filamentous processes confined to the lower third of its entire length; fifth with one setæ; sixth with four porrected setæ, as well as the greatly developed pair of setæ which are reflexed upon the limb. The antennæ have the third joint of the swimming branch fully twice the length of the second, the swimming setæ are eleven in number, the secondary appendage is, as usual in the male sex, a well-developed grasping organ, the basal joint rather longer than broad, with three setæ, the second joint very long, with two spine-formed setæ on the middle of the inner face, the third joint as long as the second, and reflexed on it.

The mandible is without masticating lobes or spines; first joint of palp with seven long, and a few short setæ on the inner margin, and one median and two distant setæ on the outer margin, the laminar appendage small, not half the length of the following joint; second joint with a fascicle of five setæ on the middle of inner margin; third joint of nearly equal breadth throughout, its inner margin with a pair of setæ near, and four setæ at the extremity, outer margin with one or two pairs of shorter setæ near the middle, succeeded by a pair of very long-ringed setæ; last joint with two ungues, one of which is very long, above which is a spine and below a seta; the second maxillæ have the outer member of the palp bearing two plumose setæ of unusual size for that position; on the limb itself teeth seem to be absent, and their place taken by lanciform spines. The penultimate limbs have their first lobe furnished with two setæ, the second with one lateral and six distal, the third with one lateral and seven distal, while the fourth lobe is entirely coalesced with the vibratory lamina, but distinguishable by its four smaller and differently constructed setæ, the vibratory lamina itself having eight large, plumose, backwardly curving setæ. Vermiform limb with few setæ. Caudal laminæ narrow, with ten ungues, the upper six small and of uniform size, the seventh much larger, the eighth small as the first six, the ninth and tenth long and slender, ciliated on their edge, as is also the seventh. In all the specimens examined a smaller unguis is, as described, interposed between the second and fourth from the end. We have only seen the male of this species.

Males only procured from tow-net gatherings when at the Zoological Station, Naples, in 1887 (A. M. N.).

[Our description of this species was written before the publication of Herr G. W. Müller's monograph, in which it is by a coincidence figured and described under the specific name which we had ourselves assigned to it. Müller, however, takes the species as the type of a new genus—*Pseudophilomedes*—distinguished from *Philomedes* by the structure of the first and second pairs of maxillæ. It

seems to us, however, that the organs, as figured by Herr Müller, do not differ, except in the degree of development of their various parts, from those of *Philomedes*, and that other members of the genus, if such deviations were admitted as generically valid, would also require new generic names. This opinion is based, we must admit, solely on a study of Herr Müller's figures. We, ourselves, have seen only the male, while the peculiarities in question are not found except in the female.]

5. **Philomedes Mac Andrei** (Baird).

(Pl. LI., figs. 7, 8; Pl. LII., figs. 5, 6.)

1848. *Cypridina Mac Andrei*, . Baird, "Note on the Genus *Cypridina*, M. Edwards, with a Description of two new species," Ann. & Mag. Nat. Hist., ser. 2, vol. i., p. 21, pl. vi. *B*, figs. 1, 2.

1850. ,, ,, . . Baird, "Nat. Hist. Brit. Entom.," p. 179, pl. xxii., fig. 1 *a–g*.

1868. *Bradycinetus Mac Andrei*, Brady, G. S., "Mon. recent Ostrac.," Trans. Linn. Soc., vol. xxvi., p. 468, pl. xxxiii., figs. 14–17; pl. xli., figs. *a–g*.

Shell subrotund, beyond which general form the rostrate frontal process, and the produced infero-posteal corner form projections; greatest height central, equal to two-thirds of the length; ventral margin rather strongly arched throughout its length, but much less tumid than the dorsal; dorsal margin remarkably, boldly, and continuously arched from the rostrate process right round the posterior extremity until the infero-posteal corner is reached; that corner is produced downwards into a short, compressed, triangular process, the front margin of which is crenated; anterior rostrate projection consisting of an underlying portion of thin texture (often shrivelling up when the shell is dried), and not unlike in form to the rostrate extremity in *P. Lilljeborgii;* overlying this is a raised calcareous portion, which forms, on each side, a horn-like process running out to an acute extremity, and strongly curved outwards and forwards; antennal sinus narrow, opening downwards, the upper side is slightly convex, and slopes upwards to form the horn-processes, the lower side is slightly convex, and sweeps round without any angularity to unite with the ventral margin; surface of valves ivory white, glabrous, and highly polished. Seen from above the form is broadly ovate; anteriorly the points of the rostral process are seen extended laterally like horns on each side, while the infero-posteal processes are projected backwards in

rostrate manner; greatest width central, equal to half the total length. Length, 2·2 mm.; height, 1·6 mm.

The antennules have the extremity of the larger setæ split into two or three lashes. The antennæ in the female have thirteen pulmose swimming setæ, which are of greater length than usual in this sex; the appendicular branch (Pl. li., fig 7), has the first joint furnished with four setæ situated close together near the base, and a seta at the extremity; the second joint bears, besides the usual hamate terminal seta, four lateral setæ, of which the first and last are longer than the two in the middle. Cleft process of mandible unequally divided, the upper and shorter portion setose; masticating spines, furnished with one strong lateral prong, and two or three other minute spine-like processes on the distal margin; third joint of palp 3–4 times as long as broad. Vermiform limb with only about eight spines (fig. 8). Caudal laminæ bearing ten ungues, the tenth strongly spined on the edge, the preceding nine finely pectinated; from near the under side of the base of each unguis there springs a group of about six moderately long simple setæ. The male is unknown to us.

Habitat.—The Minch, 1866; off the South-west of Ireland, in 159, 183, and 722 fathoms, "Porcupine," 1869 (A. M. N.). Between Lewis and Skye, 70 fathoms (M'Andrew). Oban, and Cumbrae, Firth of Clyde (D. Robertson).

Distribution.—Off west coast of Morocco, 636 metres (Marquis de Folin). Fosse de Cap Breton, Bay of Biscay, 1880 (A. M. N.).

6. **Philomedes Folini**, G. S. Brady.

(Pl. li., figs. 9, 10; Pl. lvi., figs. 11, 12).

1871. *Philomedes Folini*, . . Brady, G. S., "Review of the Cypridinidæ of the European Seas," Proc. Zool. Soc., p. 294, pl. xxvii., figs. 1–5, ♂, ♀.

1887. ,, ,, . . Sars, G, O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," Archiv. for Mathem. og Naturvidskab., p. 48, pl. iii., figs. 3, 4; pl. ix., figs. 1–13.

Shell of female (Pl. lvi., fig. 11), seen from the side, subrhomboidal; greatest height central, equal to fully two-thirds of the length; ventral margin equally and moderately arcuate throughout; dorsal much more boldly arched, the convexity being equal from the summit of the rostrate process to the commencement of the hinder margin, where the rounded declivity is more sudden; hinder margin obliquely truncate, without angularity above, infero-posteal corner produced,

and bending slightly backwards; rostrate process in front very broad, its front margin obliquely sloping backwards to the summit, which is obtusely rounded; antennal sinus widely open, its thin marginal laminæ almost meeting each other; the sinus looks downwards, its lower margin is not convex, and sloping backwards unites at an angle with the ventral margin. Surface of valves very rugose, and boldly sculptured with elevated ribs. The lowest of these commences at the bottom of the antennal sinus, and then passes round it, and round the ventral margin, a little within its edge, to the posterior extremity. Midway between the bottom of the sinus and the point where this rib turns to pass round the ventral margin, it throws out a branch rib, which traverses the valves a little below the middle, until it nearly reaches the posterior margin; a third rib, commencing at the extremity of the rostrate process, sweeps across the valves until it comes near the summit of the hinder margin, there it is deflexed, and proceeds parallel with the hinder margin, and finally unites with the first described rib at the infero-posteal corner; a fourth and fifth rib also commence in the rostrate process, and pass backwards, the one near to, and the other on the back of the valves, at about half the length of which they coalesce, and proceed backwards near the dorsal margin as one rib (Pl. LVI., fig. 12). These last ribs are best seen when the shells are looked down upon from above. The entire surface of the valves between the ribs is pitted with foveolæ. Seen from above the form is sub-hexagonal, with nearly parallel sides, which converge suddenly and angularly towards the extremities, the anterior of which is widely and abruptly truncate, the posterior broadly and bluntly mucronate and notched in the middle. The valves are very tumid, so that the breadth is more than half the length. The end view is irregularly heptagonal, the nearly parallel lateral margins ending above and below in prominent rounded angles, the two superior margins converging into an irregular arch; the basal margin nearly flat. Length 2·6 mm.; height 1·7 mm.

The antennules end in six long and some short setæ. The smaller branch of the antennæ has six setæ at the base, on the middle a great plumose, annulated, sensory seta (Pl. LVI., fig. 10), and a minute curved spine-like seta at the extremity; the swimming branch bears fourteen setæ. The frontal tentacle is of great length, and slender. The mandible has the masticating lobe as usual, bifid and hispid, and the masticating spines have one strong lateral prong, with more slender spine-points beyond it. The second maxillæ are indistinctly four-lobed, the first three lobes beset densely with setæ, fourth lobe having the outer tooth-process very large and strong, often with a lobe above near the base; inner edge plain, that is, not denticulated, the succeeding and underlying series of teeth gradually diminishing in size, all with their inner edge denticulated, and some setæ springing from base of the large tooth; beyond is the palp, which is

two-lobed, the first lobe ends in two, the second and larger in six setæ; beyond this lobe are two setæ on the body of the limb, which setæ appear to represent the third lobe of the palp, which is present in *Cypridina;* the vibratory lamina is as usual. The triangular vibratory lamina of the penultimate limbs is fringed with about fifteen plumose setæ, uninterruptedly arranged around the outer border. The vermiform last limb bears only about ten spines, six at the end, and four on the sides; at their extremity these spines are furnished with 4–6 pairs of spinules. The caudal laminæ bear thirteen ungues, of which the four last are much larger than those preceding.

The shell of the male (Pl. li., fig. 9) is much smaller and lower in proportion to its length than that of the female, and also less tumid. The rostrate process, as usual in males of this genus, is more erect, the inferior portion being absent, and consequently the antennal sinus is much more widely open. The surface of valves is pitted with foveolæ, as in the other sex, but the great ribs are almost entirely absent. A faint trace of one remains near the antennal sinus, and the second and third rib are developed, but only on the hinder portion of the shell, while the first, fourth, and fifth ribs are entirely absent. The height is somewhat less than half the length. The antennules have a large sensory seta at the hinder extremity of the fourth joint, this seta is annulated, and densely ciliated on one side of its swollen basal portion; at the extremity are two very long, annulated setæ, which are, as usual, generally reflexed upon the limb, and five other short setæ. The appendicular branch of the antennæ has the first joint short, the second long, and arcuated backwards, with three setæ on the front margin; the last joint nearly equals the second in length, and is so bent as to impinge upon that joint; on its inner face are some very minute backward-directed teeth, and at the extremity two microscopic setæ; the second seta of the swimming-branch is separated by the interval of a long joint from the first. The mandible, as appears to be universal in males of this genus, has no appearance of either the "masticating" process, or the "masticating" spines.

Fosse de Cap Breton, Bay of Biscay (Marquis de Folin, 70 fathoms, and A. M. N., 1880, in 35–65 fathoms); Messina, 10–12 fathoms (G. O. Sars).

Genus 4. Streptoleberis, G. S. Brady, 1890.

(Brady, "Ostracoda collected in the South Sea Islands."—Trans. Roy. Soc., Edinburgh, vol. xxxv., p. 515.)

Shell, seen from the side, elongated, flexuous, somewhat S-shaped; rostrate process much produced forwards, the notch being on the ventral aspect of the shell; posterior extremity narrower, produced into a pointed terminal beak, directed backwards. Animal unknown.

(Type, **Streptoleberis crenulata**, G. S. Brady, from Nouméa.)

The animal is nnknown. We had hoped from the appearance of two dried specimens of *S. favosa*, that they might have been alive when dredged. These were carefully softened and examined, but such fragments of the animal as remained were only the relics of one which had been dead when dredged, and very dirty. One or two minute fragments of limbs seem peculiar, the caudal laminæ had only six ungues, all of considerable size, and one of them (detached but probably the last) shows a large and conspicuous spine-shaped process on the middle of the outer margin, both the inner and outer margins beyond the spine-shaped process being ciliated. The antennæ resemble most closely in character the same organs in *Paramekodon*, having no appendicular branch but two setæ in its place, the basal joint somewhat smaller than usual, the length exceeding the breadth, first joint of the swimming branch rather slender.

1. **Streptoleberis favosa**, n. sp.

(Plate LIX., figs. 16–18 ; Plate LXII., figs. 20, 21.)

It is difficult to apply any term to the curious outline of this species, but it may perhaps be said that the portion posterior to the antennal sinus is in the shape of a cone, of which the hinder extremity is the summit. The ventral margin is evenly but only slightly arched throughout to the end of the posterior process, in front it sweeps inwards almost at a right angle to form the antennal sinus ; dorsal margin very boldly arched from the extremity of the rostrate process round the dorsal and posterior margins till it forms in the centre of that margin a blunt, conical termination ; the rostral process is broad and widely rounded at the extremity, where it bends downwards ; the antennal sinus is large and widely gaping. Surface of valves very uneven, sculptured with deep pittings, a ridge running parallel with the dorsal margin, and a large boss-like protuberance occupying the hinder portion of the valves, and in front of this are other irregular humps. The greatest height is equal to about three-fifths of the length, and the greatest width three-fourths of the height. Viewed from above, the form is irregularly oblong, the sides much undulated, in front the termination is very broad and of unusual length, the posterior extremity is linguiform, this portion of the outline being caused by the compressed extremity of the valves which lies beyond the boss-like protuberance. Length, 1·3 mm. ; height, ·8 mm.

We have figured in Pl. LXII., figs. 20, 21, a fragment of a caudal lamina ;

extremity imperfect, but showing a very peculiar unguis, which is slightly curved, ciliated, and bearing a small secondary spine on the convex margin.

A few specimens were dredged by the "Talisman" off the West Coast of Morocco in 1882 and 1883, in depths ranging from 836 mètres; and another specimen "off the Coasts of the Soudan," in 2333 mètres (Marquis de Folin).

2. **Streptoleberis rectirostris**, n. sp.

(Plate lix., figs. 11–13.)

Shell in general form sub-quadrate, but less high behind than in front; greatest height anterior, while the greatest width is posterior; ventral margin strongly convex in front, and sweeping evenly to the bottom of the antennal sinus, behind only very slightly arcuate, and sloping gently upwards to the extremity of the posterior projection, which is slightly below the middle; dorsal margin passing from the extremity of the rostrate process, without arcuation, obliquely upwards and backwards to the point of greatest height, thence along the central dorsal portion it is straight, or even slightly concave, behind this it slopes suddenly downwards to the point where it meets the ventral margin, and forms with it the posterior sub-central blunt projection. The rostrate process is directed straight forwards, and is sub-triangular, of moderate length, and rounded at the extremity. It forms with the arcuate backward-sloping ventral margin a widely gaping, shallow antennal sinus. Valves very finely punctate, and furnished with a longitudinal acute ridge slightly below the centre, running backwards till it nearly reaches the posterior extremity; in front a branch runs downwards from this ridge to near the ventral margin, and then bending backwards it encircles that margin; opposite the origin of this ridge another runs obliquely upwards and backwards, and ultimately passing downwards loops with the first described ridge, and with it encloses a sub-triangular space, which is the most gibbous portion of the shell; in front of the ridges described, and just behind the sinus, a much narrower ridge traverses the valves vertically; at the hinder extremity, beyond the looping-ridge described above, the valves are suddenly and greatly depressed. The greatest height is three-fifths of the length, and slightly greater than the greatest width. Seen from above the form is slightly cuneiform, excessively wide behind, where it is suddenly truncate (the posterior extremity of the shell only slightly projecting in the centre of the truncate extremity); the sides thence converge without convexity, forwards, until slightly before the rostrum they more suddenly converge, and beyond this the rostrate process is seen protruded, with its length and breadth sub-equal. Length, 1·6 mm.; height, ·9 mm.

A single specimen dredged by the "Talisman," August 11, 1883, off Arcachon in the Bay of Biscay in 2794 mètres; and another in 2333 mètres, off the coast of Soudan, July 15th, 1883 (Marquis de Folin).

Genus Tetragonodon,* n. g.

Shell of ♀ very tumid, without counting the extremities ovate; rostral process very long, projected almost directly forwards; greatest height of valves anterior; hinder extremity triangularly produced infero-posteally, slightly concave above. Antennules of ♀ six-jointed, third joint shortest; no sensory appendage. Antennæ with setæ short, not plumose; appendicular branch minute, consisting of a single joint terminated with a seta. Mandible with a masticating process cleft only at the extremity; no fixed spines on basal joint of palp, a small laminar appendage at extremity of that joint, ungues two, rather long. Second maxillæ with the three anterior lobes closely pressed together, ending in few setæ; upper tooth of great size, subquadrate, broadly truncate at the end, and smooth-edged; no lobe or setæ beyond the tooth, except those belonging to the three-lobed palp; vibratory plate well developed. Penultimate limb, as usual four-lobed. Caudal laminæ, with the ungues spined on the edge.

1. **Tetragonodon ctenorhynchus**, n. sp.

(Plate lviii., figs. 1–8.)

General form of shell of female, ovate, excessively tumid, so that the breadth nearly equals the height; slightly concave on the upper part of the posterior margin, and with a long pointed, nearly erect rostrate process in front; greatest height equal to four-sevenths of the length, and situated just in front of the middle, from which point the outline declines gradually backwards; ventral margin from the bottom of the antennal sinus projected boldly outwards, and forming a very convex sweep for two-thirds of the length, behind this it gradually slopes upwards to the hinder extremity; the dorsal margin passes from the extremity of the porrected rostral process with moderately convex arcuation backwards to about one-half the length of the valve, behind this point the arcuation is only slight, until on reaching the commencement of the hinder margin, it sweeps down obliquely and with slight concavity to the point where it meets the ventral margin and with it forms a blunt angle at the infero-anteal corner. In front the rostral process is of remarkable length, and running out to a sharp point, is projected forwards, an ! only slightly downwards; beneath it the antennal sinus lies very widely open; the surface of the valves is everywhere pitted with little

* τετράγωνος, square; ὀδών, a tooth.

round cells. Seen from above the form is widely ovate, the greatest breadth, which is central, being equal to more than half the length; the margins are boldly and evenly arched; in front the rostrate process is seen slightly projected, and furnished at the sides with four or five flattened nodulous processes; the posterior extremity is mucronate. Length, 2 mm.; height, 1·3 mm.

The antennules (fig. 3) have the proportionate length of the joints as is usual. Antennæ (fig. 4), with basal joint subquadrate, its length and breadth subequal, remarkably small and much shorter than the first joint of the swimming branch; first joint of the swimming branch slender, slightly arcuate and longer than the rest of the limb; setæ ten, short, ringed, but not plumose; a spine-formed seta on the basal joint of the antenna close by the origin of the appendicular branch, which consists of one short joint, and is naked and broad at the end, to one corner of which is attached a long terminal seta.

Mandible (fig. 5), with "masticating" process of basal joint long, and cleft only for a short distance at its extremity; first joint of palp without cleft spines, but furnished on the inner margin with six short, stout, ciliated setæ, and a longer seta on the central line between the more distant pairs of setæ just described, the upper margin having a seta towards the extremity, followed by a pair of setæ and a laminar appendage, which is about half the length of the following joint, and ends in two setæ; second joint with a pair of ringed setæ on the lower margin, preceded by a minute seta, all of these ciliated only on their central portion; third joint only slightly narrowing from the base to the extremity, bearing five ringed and ciliated setæ on the central portion of the upper margin, on the lower margin a single seta, and, then, near the extremity a pair of spines; last joint minute, with two short setæ and two long, gently curved ungues, which are crenated at the end.

The second maxillæ have the lobes very small and pressed close together, with very few setæ, apparently not more than four to any one lobe; tooth enormously developed (fig. 6), occupying by far the larger part of the end of the member, sub-quadrate in form, broadly truncate at the end, and smooth edged; no setæ beyond the tooth, except those belonging to the small palp, which consists as usual of three divisions, the first furnished with two, the second with four (?), the third with one (?) seta; vibratory lamina large, edged with about thirty-six setæ. Penultimate limb consisting, as usual, of four lobes, the first with three, the second with six, the third with five, the fourth with five setæ.

Vermiform limb with twelve spines, six of which are at the extremity; the spines are furnished with three or four pairs of spinules (fig. 7). Caudal laminæ (fig. 8), rather narrow, bearing nine not crowded ungues, all strongly spined on the edge; in the smaller ungues the spines are only seen near the base, but in the larger throughout the greater part of their length.

The exact locality is unknown to us. The specimens were dredged by the "Talisman," July 11, 1883, in 932 mètres, and received by us from the Marquis de Folin; the date would lead us to suppose that *T. ctenorhynchus* was taken off the coast of Morocco.

The shell, in this species, is quite different in form from any other species which is as yet known; and very marked characters are present in the animal in the peculiar form of the appendicular branch of the antennæ; in the character of the "masticating" process of the mandible, in the remarkable large tooth of the second maxillæ, and the reduction in size of the other part of that limb; in the very rudimentary character of the vibratory lamina of the penultimate limbs, and in the spination of the ungues of the cauda, these ungues are sometimes ciliated, sometimes crenated, sometimes minutely denticulated, or serrated, but in no other case do we know them so strongly spined as in this species.

2. **Tetragonodon erinaceus**, n. sp.

(Plate LIX., figs. 14, 15.)

Shell, seen from the side, doubly bent, in general form ovate, with the anterior rostrate portion obliquely directed downwards, and the posterior sub-central triangular projection bent slightly upwards; ventral margin regularly and evenly arched throughout, in front penetrating at the antennal sinus to nearly half the entire height of the valves, thence the rostrate process is directed obliquely forwards and downwards to a remarkable length, with the extremity narrow; the antennal sinus is very widely open; the dorsal margin is anteriorly gently arched to the extremity of the rostrate process, centrally it is nearly straight, posteriorly the declination is sudden but well rounded; the posterior extremity is produced into a triangular compressed process, of which the upper side is nearly perpendicular to the hinder margin, while the lower is a portion of the continued sweep of the ventral margin. The total length is somewhat less than twice the greatest height, and the greatest breadth is equal to five-sixths of the height. The valves have a nearly perpendicular depression across them slightly behind the middle, and their entire surface, except the extremity of the posterior triangular projection, is covered with spinous processes, which for the most part are acute at their termination, but in some cases, especially on the hinder ventral portion of the valves, these spinous processes have clavate terminations. Viewed from above the form is ovate, the sides arched, the great anterior rostrate process projected in almost sub-quadrangular form, and the posterior triangular process appearing as a small rostrate projection. Length, 2 mm.; height, 1·1 mm.

Off Cape Blanco, coast of Morocco, "Talisman" Expedition (Marquis de Folin).

Genus 7. Paramekodon,* n. g.

Shell in ♀ oval, excessively tumid, breadth sub-equal to height, antennal sinus a mere concavity, in front of which the rostrate process is projected directly forward; surface of valves in type species punctate and hispid. Antennules (Pl. lix., fig. 3), six-jointed, without sensory organ on fourth joint, with terminal setæ sub-equal, two of them of remarkable character, flattened, membranous (fig. 3 *a*), and closely waved in wrinkles; antennæ without any appendicular branch, in its place a large-ringed, plumose seta (fig. 4); mandible (fig. 5) with masticating process divided, but only at the extremity; no peculiar spines on the second joint, but the laminar appendage at its extremity well developed, limb ending in a single unguis of great length; first maxilla (fig. 6) short; second maxilla devoid of anterior lobes, teeth enormously developed, the upper (fig. 8) consisting of a great sub-oblong plate, with spiny processes on the margin, and terminating at the anterior extremity in a large fang, vibratory lamina well developed (fig. 7), external palp consisting of a single lobe; penultimate appendages without vibratory lamina (fig.) 9.

Paramekodon inflatus, n. sp.

(Pl. lix., figs. 1–10.)

Shell of female regularly and broadly ovate, beyond which the rostrate process projects forward, and at the infero-posteal corner there is a slight lip-like protrusion of the valves; the antennal sinus is small, caused by the junction of the perfectly erect obtusely rounded rostral process with the natural and continued inward sweep of the ventral margin; ventral and dorsal margins very bold and evenly arched, the latter with a slight sign of angularity at its junction with the somewhat obliquely truncated upper portion of the posterior margin, the lower portion of which margin is slightly protruded, as already mentioned. Form excessively tumid, greatest height central, equal to five-sevenths of the length, and the breadth sub-equal to the height. Seen from above, the outline of form, except the extremities, is almost identical with the lateral view; greatest breadth central, sides very boldly and evenly arched, posterior extremity very broad; anterior, with the rostral portion much more compressed. Valves rather thin, surface very finely punctate, and sparingly hirsute.

Antennules (fig. 3) six-jointed, first joint longer than the combined length of two following joints; second and fourth joints sub-equal on the inner margin, the former the longer on the outer; third and fifth joints sub-equal, and each about half

* παραμήκης, oblong; ὀδών, a tooth.

the length of the second; last joint minute: second, third, and fourth joints with one ringed and plumose seta on the upper margin, the second with two very minute spinules on lower margin, the third with one, and the fourth with two distal, long, ringed, and plumose setæ; penultimate joint with two minute setæ on the upper part of the extremity, and one long-ringed seta on the lower corner; last joint with five setæ of nearly equal length, two of which are of very remarkable structure, apparently membranaceous and flattened, being very closely and minutely wrinkled on every part, and (fig. 3 *a*) wholly destitute of cilia or other appendages. Antennæ with basal joint smaller than usual; swimming-branch nine-jointed, the last joint minute, with only two setæ, one of which is very small; nine setæ in all; no appendicular branch (fig. 4), but in the place usually occupied by it there is a very large-ringed plumose seta, near the origin of which are three very small, but distinctly ringed setæ.

The mandible has the basal joint furnished with a long masticating palp (fig. 5), cleft at the extremity for a short distance, and there hirsute; first joint of palp without masticating spines but with fascicles of very minute cilia on the side; inner margin with four setæ, two of which are small but ringed, the other large, ringed, and densely plumose, outer margin on the distal half with one long-ringed ciliated seta, followed by a pair of similar setæ, and at the extremity a well-developed laminar appendage, which is nearly two-thirds the length of the following joint, and ends in two setæ; second joint equal in length to about two-thirds of the first, with only one seta on inner, and none on outer margin; third joint more than half as long again as the second, inner margin with three series of minute cilia, followed by a spine, and then a pair of spines, outer margin with a fascicle of three or four setæ at the middle; last joint minute, bearing remarkably long and slender well-curved ungues, which exceed in length the two preceding joints, and below the ungues are two setæ.

First maxillæ (figs. 6, 6*a*) very short, with three lobes, the upper ending in three spines of remarkable character and a seta, the second in two spines and two setæ, the third is furnished with four setæ, the apical spines of the first two lobes have a spine-like process near the extremity of their outer side, the inner side in one case has the latter half very delicately serrated, in another case the lower half of the margin bears five or six spinules, and the distal half is finely ciliated; the distal margin of the lobe-bearing joint has a very large plumose seta below, a fasicle of three smaller setæ half-way up, and a large plumose seta above; the following joint has one seta on the upper margin, and one near the infero-postea-corner; the last joint bears a long slender unguis and three or four setæ.

In our dissection of the second maxillæ (fig. 7) we are unable to find any lobes or seta anterior to the teeth. There are two teeth. The outer of these (fig. 8) is of enormous size and consists of an irregularly oblong plate, or jaw, laid

horizontally. Beginning from behind, the upper margin of this plate throws out a vertical process divided into four teeth at the extremity; this is followed, after an interval, by another similar process divided into three teeth; after another interval another process with two teeth; and then the extremity rises into a great fang five or six times the length of the dentated processes which precede it. Below this tooth lies a second, in which on the further portion of the plate or jaw are some teeth which we cannot clearly see; but near the anterior extremity is a fang-shaped process, which has on its inner margin three denticulations; this is followed by the terminal fang, which is much smaller than that of the first jaw (not quite half its length), and instead of being a simple fang, as in that case, bears 3–6 denticulations in front and three nodulous processes on the side at the back. On the side of the first described jaw are two setæ placed close together. Beyond the jaws is the usual palp, which here is represented by a single lobe, with one lateral and four terminal setæ. Just behind the base of the palp are two small-ringed setæ; beyond these again comes the vibratory lamina, which has a somewhat flexuous outline, and is firinged with about forty-three plumose setæ. The penultimate appendages (fig. 9) consist of three lobes, the inner with one lateral and four apical setæ, the second with four apical setæ, the outermost with three apical setæ, and five large plumose setæ on its outer margin; the character of these setæ seem to suggest that they represent the coalesced vibratory lamina, which as a lamina is wholly absent.

The vermiform limb has six terminal and one pair of lateral, long, slender spines,* with 3–5 pairs of spinules near the extremity; the tips of the end of the appendage itself are furnished with a few (we count four) simple, curved, spine-like processes. The caudal laminæ (fig. 10) are about twice as long as their breadth at the base; the ungues are ten, and being well separated at their origin occupy the greater part of the hinder margin; the third from the end is smaller than the fourth and second. The larger ungues are ciliated on the edge; the last is about the same size as the penultimate.

A single specimen was dredged by the "Talisman" off the coast of Morocco, July 6, 1883, in 1435 mètres (Marquis de Folin).

The single specimen which we have seen had been preserved dry. After drawing the shell it was macerated, and the animal being thus restored, has been dissected, figured, and described.

* These curious processes we have in this work called spines, but they are not so here, and very often they are closely annulated in structure.

Fam. II.—RUTIDERMATIDÆ.

Shell oval, truncate behind, antennal sinus very shallow, no overhanging rostral process, surface of valves rugose. Antennules without sensory organ. Antennæ without any secondary branch. Mandibular palp, with last joints of great size, forming a large chela. No branchiæ.

Genus Rutiderma,* n. g.

Shell oval, truncate behind, antennal sinus very small, no overhanging rostral process; surface of valves in type species rugose. Antennules (Pl. LVIII., fig. 12) without sensory appendage, a ringed seta taking its place. Antennæ (fig. 13) without any secondary branch. Palp of mandible (fig. 14), with last joint very massive, terminating in a strongly developed chela, formed by two very large processes, which are hooked at their extremities, the outer one flattened and pectinated on its inner face. Outer tooth of second maxillæ three-lobed, lobes plain-edged. Caudal laminæ (fig. 16) having few ungues.

The shell approaches in form to that of *Sarsiella*, but is oval instead of round, and the infero-posteal corner only slightly prominent; while anteriorly there is an antennal sinus of small size. The structure of the palp of the mandible is most remarkable. The account we give of the animal is derived from the maceration of specimens which have been preserved in a dried state for twelve years, many minute details, therefore, are wanting, and some of those given perhaps will prove to be not absolutely correct.

Rutiderma compressa, n. sp.

(Plate LVIII., figs. 9–16.)

General form of shell of ♀ oval, vertically truncated behind. Ventral margin well arched throughout to the infero-posteal angle; dorsal margin also boldly and evenly arched, but with very slight sinuses in two or three places, more especially just before reaching the supero-posteal corner; hinder extremity broadly truncated and bilobate, so as to leave a slight central sinus; anterior extremity rounded; antennal sinus very small and shallow, its upper margin forming a right angle with the bottom of the sinus, there being no vestige of a beak. Surface of valves very irregular, punctated with foveolæ

* ῥυτίς, a wrinkle; δερμα, the skin.

all over, and sculptured with numerous riblets, two of these pass longitudinally round the ventral portion; another starting from the anterior extremity as its base gradually approaches the dorsal margin which it nearly meets at about two-thirds of its length; another longitudinal riblet is situated a little above the centre, and passes backwards till it approaches the hinder extremity, when it sweeps downwards and after forming two lobes unites with the ventral riblets; at the position of the two lobes just mentioned the valves attain their maximum obesity, and beyond this they are suddenly depressed to the flattened hinder extremity; a little in front of the middle of the shell there is a nodulous protuberance lying between the two uppermost riblets. Greatest height sub-central, equal to nearly three-fourths of the length; greatest width equal to only half the height. Seen from above the form is cuneate, abruptly truncated behind, with a slight central protuberance caused by the compressed hinder extremity, which juts out beyond the point of maximum breadth of the valves; from the truncation the sides converge forwards, at first only gently, but at two-thirds the length more suddenly, and meet at a slightly obtuse extremity in front. The end view shows that when the valves are broadest they are nearly equally so throughout their height. Length, 1·5 mm.; height, 1 mm.

Female (?) Frontal tentacle very long and slender. Antennules (fig. 12) five-jointed, geniculated at the end of the first joint, which is one-third longer than the second; second, third, and fourth joints sub-equal in length, last minute; the second joint bears one seta on the outer margin; the third one seta on each margin at its base, a seta at the end of the upper, and two rather long annulated setæ at the end of the lower margin; the fourth two minute setæ on the upper and a large annulated seta on the lower margin at the extremity; last joint with three large annulated setæ, and three of smaller size.

The antennæ (fig. 13) have the basal-joint pyriform, not so broad or large as usual, the length greater than the breadth; swimming-branch also rather more slender than usual, nine-jointed, the first joint long and slender, second to eighth, each with a swimming seta, last with five setæ, the furthest minute, and the next also short; appendicular branch altogether absent.

The palp of the mandible (fig. 14) is of very remarkable structure, consisting of only two joints and a chela; the mandible itself has a bifid masticating process. The first joint of palp has on the lower margin two masticating spines which are tuberculated on their edge, and two setæ, one of which is in front of and the other behind these spines; a third seta is borne at the end of the outer margin; second joint of immensely strong build, the outer margin very boldly arched, and bearing at its centre two small setæ, and one small seta at the inner-distal corner, otherwise the joint is naked; to its extremity is attached a very large and strong chela, the outer member of which is the shorter, falcate,

and smooth-edged, at its inner base are two long and two short spine-like processes, and further back two minute setæ; inner member also very strongly built, falcate, its lower margin, towards the extremity, bending slightly backwards, and then curving suddenly inwards, so as to form a hook-shaped apex, which closes over the end of the outer member, while its upper margin is flattened out to a knife-like serrated edge.

First maxillæ short, stout, and strong; first joint with two (or three?) lobes edged with spines, some of which are very strong, and denticulated on the edge, and others are serrated on one edge; second joint very short; third broader than long, boldly arched on the outer side, near the extremity of which is a single seta; last joint ending in a few short spines and setæ and two ungues, one of which is large and strongly denticulated on the edge.

Second maxilla with outer tooth large (fig. 15), very broad, and trifid distally, without any denticulated margin; number of setæ small, all we can see are about six inside the tooth, and two beyond it; palp, with central member ending in three setæ; vibratory lamina large, semicircular, fringed with about thirty-four long setæ. The foregoing must be regarded as an imperfect account of these maxillæ. Vermiform limb with about six spines at the end and four on the sides; the spines have about six pairs of spinules near the extremity. Caudal laminæ (fig. 16) short, with only six ungues, of which the three uppermost are small and spine-like, the last three remarkably strong and blunt at their extremities, the last nearly twice as long as the penultimate and ciliated on the edge.

This species was found sparingly amongst the proceeds of two dredgings sent to us by M. de Folin; one of these was from off the Cap de Peñas (Bay of Biscay), the other from the Fosse de Cap Breton; depth, 150 mètres.

Fam. III.—**SARSIELLIDÆ**,* Brady and Norman.

Shell, round or oval in ♀, or obliquely truncate in ♂; strongly calcareous and the surface generally roughly sculptured, but sometimes nearly smooth; no antennal sinus in ♀, in ♂ sinus widely open and shallow; infero-posteally either simply rounded or more usually produced into a process of considerable size. Antennules (Pl. LX., fig. 8) five-jointed; antennæ ♀ (fig. 9) with appendicular branch scarcely developed, in ♂ small, but formed for grasping. Mandible (fig. 10) with basal joints of palp very stoutly built, penultimate joint very short, last joint terminating in a single claw. Second maxillæ (fig. 13) wholly devoid of tooth-processes; third

* The whole of our MS. was written, and the plates prepared, before the publication of G. W. Müller's work. We have slightly modified the characters we had given of the family *Sarsiellidæ*, but for the rest have left the MS. as it was, retaining as a genus *Nematohanoma*, which G. W. Müller considers to be the male of *Sarsiella*.

maxillæ only represented by a single lobe, the vibratory appendage absent; vermiform limb (figs. 14, 15) of usual structure; caudal laminæ (fig. 17) with few ungues, rapidly increasing in length. No branchiæ.

* No antennal sinus.

Shell round, with a largely developed conical extended process at the infero-posteal corner, ... *Sarsiella.*

[Shell oval, infero-posteal corner rounded, a small projected point on the lower half of the anterior margin, *Eurypylus.*]

** Antennal sinus shallow, widely open, shell obliquely quadrate, posterior margin very oblique, and infero-posteally much produced, ... *Nematohamma.*

[Genus Eurypylus, G. S. Brady, 1869.]

"Les Fonds de la Mer," vol. i., p. 141.

[Valvulæ testæ duræ, calcareæ, superficie dense foveolata, incisurâ nullâ; testa a latere visa rotundata, extremitate anticâ infra medium rostro brevi rotundato prædità, posticâ rotundatâ; supra visa clavata, antice late rotundata, postice attenuata. Animal fere ignotum, antennæ superiores certe fasciculo setarum perbrevium armatæ.

Eurypylus petrosus, G. S. Brady, *l. c.*, p. 141, Pl. xviii., figs. 1, 2.

Testa a latere visa rotundata, altitudine maximâ $\frac{3}{4}$ longitudinis circiter æquante in medio sitâ, extremitate posticâ rotundatâ, margine superiore leviter, inferiore valde convexo: supra visa clavata, latitudine maximâ dimidiâ longitudinis parte minore versus extremitatem anticam sitâ, lateribus postice convergentibus, extremitate anticâ rotundatâ in medio paulo mucronatâ, posticâ obtuse acuminatâ. Superficies valvularum foveolis rudibus sculpta. Long. 0·0008.

A single specimen from St. Vincent, Cape Verde Islands.

The palp of the mandible closely resembles that of *Sarsiella;* the last three joints are wholly devoid of setæ, the penultimate very short, about one-third the length of the preceding; the ante-penultimate joint is furnished, apically below, with an unguis, the penultimate with a longer unguis, the last with a still larger one; these ungues are gently curved, and in consequence of the shortness of the last joints their bases are close together. The caudal laminæ bear only four ungues; the distal one occupies the termination, and is of large size, and ciliated on the edge, the next is about half its length; the two upper are minute, and spine-like.]

Genus 1.—Sarsiella, Norman, 1869.

("Last Report Dredging, Shetland," Brit. Assoc. Rep., 1868 (1869), p. 293.)

The female has the shell highly calcareous, usually roughly sculptured, sub-rotund, no antennal sinus, a produced process at the infero-posteal corner. Antennules five-jointed, second, third and fourth joints sub-equal, the fourth terminated by three long and several short setæ, but without a sensory appendage, a long annulated seta taking its place. Antennæ with the accessory appendage reduced to a nodule bearing a single short seta. Mandible without masticating process or masticating spines, the whole limb remarkably free from setæ; two terminal joints very short; each of these and also the preceding joint terminating in one strong curved unguis, the three ungues close together and increasing in length successively. The first maxillæ have four lateral setose lobes, the terminal joint is very short and broad, and at its extremity bears five stout spine-like setæ, which are ciliated on their edges, and spread out like the fingers of a hand. The second maxillæ bear three lobes and a one-jointed palp, all furnished with setæ but wholly without tooth-like organs or strong pectinated setæ; vibratory lamina well developed. Third maxillæ very small, consisting of a simple rounded lobe, setose at the edge; no vibratory lamina. Last vermiform limbs of the usual form. Caudal laminæ with few (6–7) ungues.

This genus was established by A. M. N. in 1869, to receive a remarkable ostracod which he had dredged in the Shetland seas. Since that time four additional species have been described by G. S. B.,* from the South Sea Islands, and we are now enabled to add a sixth from off the Soudanese Coast.†

1. **Sarsiella capsula**, Norman.

(Pl. lx., figs. 1–4, 18.)

1869. *Sarsiella capsula*, . . Norman, "Last Report Dredging among the Shetland Isles," Brit. Assoc. Rep., 1868, p. 293.

1887. ,, ,, . . Sars, G. O., "Nye Bidrag til Kundskaben om Middlehavets Invertebratfauna: iv. Ostracoda Mediterranea," Archiv. for Mathem. og Naturvid., p. 57, pl. iii., figs. 5–7; pl. x., figs. 1–13.

1894. ,, ,, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 214, pl. iv., figs. 4–6, 8–10, 22, 25, 27–29, 31, 33–35, 37, 48; pl. viii., figs. 6, 7.

* G. S. Brady, "Ostracoda collected by H. B. Brady in the South Sea Islands."—Trans. Roy. Soc. Edinburgh, vol. xxxv., 1890, pp. 516, 517.

† Since writing the above a seventh species, *S. lævis*, has been described by G. W. Müller.

Shell seen from the side nearly circular, the infero-posteal corner produced into a large conical process, ventral and dorsal margins nearly equally semicircular; anterior margin widely and regularly rounded, and circularly uniting with ventral and dorsal margins; surface very rugose, with concentric greatly elevated carina enclosing a deep hollow in the centre of the valve; from the exterior of the carina numerous radiating ribs pass on all sides to the margin; the interstices of these ribs and the central portion of the shell are sculptured with circular pittings. Seen from above, the form is very irregular, but upon the whole slightly cuneiform; greatest width posterior, at which extremity it is abruptly truncate and in the centre of the truncation the posterior conical process is seen projected; from the truncated end the sides converge gradually at first, and then more rapidly towards the anterior extremity, which is tolerably wide, and slightly emarginate in the middle. End view with concave sides, dorsally arched, and ventrally truncated. The valves are very much compressed in their centre. Length, 1·2 mm.; height, 1 mm. The male is unknown.

Antennules with second third and fourth joints sub-equal in length, the second joint with one seta on front margin, the third with two on the front, and three on hinder margin, the fourth with one long annulated seta which is not ciliated or filiferous, fifth joint with three long annulated setæ and some shorter setæ, at the distal extremity of hinder margin. Antennules bearing nine swimming setæ on the main branch, secondary branch rudimentary, consisting only of a little nodulous process carrying one short seta. Mandibular palp strongly unguiculate; mandible itself without any masticating process; first joint of palp without masticating spines or laminar appendage but with two or three small cilia on the hinder margin; second joint curved, broad and strong, the length not twice the breadth; fourth joint extremely short; each of the last three joints bearing a strong curved unguis, the three ungues being close together, and the distal longer than the preceding; the joints are wholly devoid of setæ, spines, or cilia. The first maxillæ (fig. 18) bear two or three lateral ciliated lobes, the penultimate joints bears a long spiniform ciliated seta on each side, and the last which is about three times as broad as long, has its extremity furnished with five short stout cuneiform spines, which are ciliated on the edges quite to the base, and spread like the fingers of a hand. The second maxillæ consist of a two-jointed member bearing at the extremity seven or eight setæ, but entirely devoid of teeth or other structures of allied character; a semicircular seta-edged vibratory lamina is present. Caudal laminæ with six ungues, which rapidly increase in length, the last being produced and greatly longer than the preceding.

Habitat.—St Magnus Bay, Shetland, 30–60 fathoms, 1867; off Valentia, Ireland, 1870 (A. M. N.).

Distribution.—Off Capri, Bay of Naples, 1887 (A. M. N.). Messina and Syracuse in 10–20 fathoms (G. O. Sars).

2. **Sarsiella globulus**, n. sp.

(Plate LX., figs. 5–17.)

Seen from the side the outline is circular, the height equal to the length exclusive of the posterior projection, which is longer and situated higher on the hinder margin than in the last species. The margins from above and below this projecting process form a complete circle round the ventral, anterior, and dorsal margins; the surface of the valves round the sides is more evenly convex than in *S. capsula*, but an oblique central portion is flattened and margined by riblets, the lower of which commences in front, a little within the anterior border and slightly below its centre; it thence passes downwards and then backwards towards the conical posterior process, at some distance from the base of which it suddenly bends upwards towards the dorsal margin, which it does not quite reach; the second riblet commences anteriorly a little above the first, and passes in an oblique direction across the valve towards the dorsal margin near which, and at no great distance from the termination of the previously described riblet, it ends in a blunt upraised point; the surface is everywhere punctated. Seen from below, the general form is oval, but towards the hinder extremity the outline becomes irregular owing to the prominence of the rib-bordered areas already described, while in the centre behind the posterior conical process is seen exserted. Greatest length, 2 mm.; height, 1·9 mm.

The antennules (fig. 8) resemble in every respect the same organs in *S. capsula*, except that the second joint has, besides the seta on the front margin, about three minute spinules, and one similar spinule on the hinder margin. The mandibular palp (fig. 10) has a much longer seta on the first joint in addition to the short spine-like setæ, and the terminal joint has a small secondary unguis in addition to the large unguis. The first maxillæ (fig. 11) have four lateral lobes, two of which bear six setæ, the third three, the fourth two; the extremity of the limb is armed as in *S. capsula*, but the terminal joint is rather longer. The second maxillæ (fig. 13) consist of three lobes and a single-jointed palp; the first lobe bears one, the second three, the last nine setæ; the palp ends in three setæ, and there is another seta on the limb at the base of the palp. The caudal laminæ (fig. 17) bear seven ungues, which are remarkably long and slender, and the last only proportionately longer than the preceding.

Off the coast of Soudan, North Africa, in 2333 mètres, "Talisman," July 15, 1883, a single specimen (Marquis de Folin).

Genus 2. Nematohamma,* n. g.

Shell of male obliquely subquadrate, hinder extremity very widely and very obliquely truncated, rostrate process not at all projected downwards, being abruptly truncated inferiorly; antennal sinus widely gaping; surface of valves rugose. Antennules bearing a nodiform appendage at the hinder extremity of antepenultimate joint, the appendage covered with a dense cluster of very long filaments, and also furnished with a long annulated seta. Antennæ with secondary appendage small, but formed for grasping. Mandible without any masticating lobe or peculiar spines at the base, third joint of palp very short, last joint carrying a single unguis. Copulatory appendages having terminal hooked processes.

Female unknown.

The curious dense cluster of very long filaments attached to a short clavate process on the antennules, and the structure of the mandibular foot, are the chief characters which separate the type of this genus from all other *Myodocopa*.

Nematohamma obliqua, n. sp.

(Plate lii., figs. 1, 2; Plate liii., figs. 12–15.)

Shell of ♂ subquadrate, abruptly and very obliquely truncated behind; greatest height subcentral, equal to three-fifths of the length; ventral margin with only slight arcuation; dorsal margin highly convex centrally, but only gently arcuated towards the extremities; hinder margin abruptly widely and obliquely truncated, forming distinct angles at its junction with ventral and dorsal margins. The anterior extremity is bluntly rounded, without any sign of a beak, the lower side rising at right-angles from the bottom of the antennal sinus, which is shallow and completely open above, with its lower edge gently convex. Surface of valves very uneven, punctated, and furnished with many elevations and hollows; a strongly developed rib crosses the anterior extremity; the central portion of the shell is depressed, and surrounded by rib-like elevations, enclosing a subquadrangular space, which is wider behind than in front. The lower much elevated riblet which encloses this space is waved, being incurved in front, then boldly convex before it sweeps upwards at some distance from the hinder extremity to meet at a sharp and nodulated angle the riblet which bounds the enclosed space above; that riblet is arcuate, and runs at some little distance

* *νῆμα*, a thread; *ἄμμα*, a knot, *i. e.* a knot of filament in allusion to the appendage of the antennules.

within the dorsal margin; behind the enclosed space the shell is depressed, and a riblet passes from the infero-posteal corner to the surrounding riblet-wall of the enclosed space. Seen from above, the greatest width is behind the middle and equal to about two-fifths of the length: the form is narrowly-ovate, the anterior extremity wider at its termination than the posterior, which is projected in somewhat rostrate form beyond the part which is elevated and enclosed (on the side view) by the bounding riblets. Length, 1·25 mm.; height, 0·8 mm.

Antennules in ♂ (Pl. LIII., fig. 12), have the first and second joints sub-equal in length, the former without setæ, the latter with one annulated and ciliated seta on the middle of the front margin; third joint excessively short and rudimentary,* fourth and fifth joints sub-equal, each rather shorter than the second; the former with one proximal and one distal seta on the front margin, a pair of long setæ on the middle of the hinder margin, and at its extremity a remarkable appendage, which is another form of the sensory organ of *Cypridina*. This sensory appendage consists of a short clavate process which is rather longer than wide and has its broadly-rounded extremity covered with a dense brush of filaments of such a length that they extend even beyond the terminal setæ of the limb; rising also from the distal side of the process, but so hidden by the mass of filaments that its base is difficult to detect, is a long annulated seta which stretches forward, side by side with the similar setæ of the last joints, sixth joint rudimentary; termination of limb with four or five long setæ, as well as others which are small.

The antennæ have the swimming-branch furnished with nine setæ, and its third joint only slightly shorter than the second; the secondary appendage (fig. 13) is small, but formed for grasping; its basal joint coalescent with the trunk, and indicated only by two minute setæ; the second (first free) joint is flexuous, about three times as long as broad, with two short spines,† last joint cylindrical, simple, blunt at the extremity, and reflected on the preceding joint.

Mandible (fig. 14) without masticating process or peculiar spines, basal joint very stout, first and second joints of palp curved, the former the longer, with three or four spinules on the inner margin, and near the extremity of the outer margin two small ringed setæ; second joint with a stout ringed and ciliated seta at the end of the inner margin; third joint with a single long ringed seta on each margin, last joint very minute, terminating in a single, long, gently curved unguis which nearly equals in length the last three joints, and bears a spine point half way down the outer margin; there are one or two minute spinules by the base of the

* The limb, viewed from one side, appears to have such a joint, but on the other it is scarcely indicated.

† We call them spines, for they are spiniform; but they seem to have an annulated structure.

unguis.* The copulating appendages (fig. 15) have each lobe terminating in a large hook-shaped claw; caudal laminæ (fig. 15) with five rather long ungues, which gradually increase in length distally, the last, however, much longer than the penultimate; they are all strongly ciliated at the edge.

Habitat.—Dredged in 112 fathoms, off Valentia, Ireland, in 1870 (A. M. N.) Birterbuy Bay, Ireland, 1874 (A. M. N. and D. Robertson).

Fam.—**HALOCYPRIDÆ.**

Valves sub-equal, very thin and flexible, composed of two tunics, which are scarcely adherent except at the edges; hinge-margin straight, almost, or quite, edentulous; anterior extremity produced more or less into a beak-like prominence with a subjacent sinus. Eyes wanting, or present only in an abnormal condition. Projected forwards in the median line between the antennules is a frontal tentacle usually clubbed at the extremity.† Antennules dissimilar in the two sexes; in the female weak, indistinctly jointed, immobile and bearing a fascicle of sensory setæ; in the male larger, distinctly jointed, mobile, and with elongated setæ. Antennæ natatory and, as in Cypridinidæ, bearing a secondary branch, which in the male has a prehensile appendage. Mandibles well developed, biting plate dilated and toothed at the apex : palp large, four-jointed, geniculated, basal joint produced and forming a large chewing dentated lobe in contact with the biting apex of the mandible; terminal joints bearing curved setæ or spines. Two pairs of maxillæ. Two pairs of feet, the first pair the larger and dissimilar in the two sexes; second pair very small, both pairs having branchial laminæ attached near the base. Caudal laminæ short and clawed on the posterior margin. Copulatory organ of the male single, sinistral.

Sub-fam.—**Conchœcinæ.**

Shell elongated, its length usually very much greater than its height; rostral process well developed, and having a well-marked subjacent sinus. Frontal tentacles different in the two sexes; in the male surrounded by a tentacular circlet which springs from the second joint of the antennule, and ending in a club-shaped, angularly-bent capitulum. Peduncle of the antennules elongated and more massive in the male than in the female; in the female bearing one long, simple, terminal seta and four much shorter sensory filaments which are of equal length; in the

* It will be observed on comparison of our figure and description of the limb, which stand as they were before Müller's work reached us, that they much more closely accord with the figure of this organ in his *Sarsiella lævis* ♂, than that of his *Sarsiella capsula* ♂.

† We employ the term "capitulum" for this clubbed extremity.

male there are three long, but unequal setæ, and two much shorter sensory filaments; the proximal seta much the longest, and armed in a part of its length with more or less numerous minute marginal spines or hooks. Secondary branch of the antenna bearing, on the basal joint a marginal, nipple-shaped prominence; natatory setæ scarcely longer than the peduncle, slightly dilated, and lancet-shaped towards their apices. Basal joint of the mandible palp elongated, and usually as long as, or longer than the united lengths of the three following joints. Second maxilla much shorter than the first foot which, in the male, is very large and ends in a lash of three equally long setæ.

Many species belonging to this sub-family we have had no opportunity of examining; in such cases we have simply given descriptions condensed from those of Professors Claus and G. O. Sars. We are, however, much indebted to both of those authors for their kindness in supplying us with examples of several of the species described by them.

Genus 1. Conchœcia, Dana, ex. p.

Shell elongated, subquadrangular, posterior extremity truncated, sometimes smooth, but usually ornamented with a striated or reticulated sculpture either towards the margins or over the general surface of the shell; rostrum and sub-rostral sinus well developed; hinge processes absent or only feebly developed. "A group of club-shaped gland sacs near the posterior end of the dorsal margin, another group at the upper angle of the posterior margin of each valve, and a third at the infero-posteal angle of the right valve." Antennules of the female slender, cylindrical, bearing four sensory tubular filaments, and one long, slender seta, those of the male with three equal elongated setæ, and two unequal sensory filaments. Antennæ greatly developed, basal portion very large, pyriform, elongated, natatory branch 7- 8-jointed, first joint elongated, the rest very short; secondary branch two-jointed, basal joint forming a flattened expansion, last joint short and bearing in the female a lash of filaments, and in the male an additional falcate process. Labrum hood-like, with irregular processes in front. Labium bilobed, inner margins of lobes setiferous. Basal joint of the mandible-palp as large as, or larger than the remainder of the limb (Plate xvi., fig 17) bearing at the apex a single stout plumose seta; last joint with three ciliated spines on the inner margin. First pair of maxillæ (fig. 18) composed of two masticatory lobes, with a large two-jointed palp which is armed with several curved spines. Second pair of maxillæ pediform (fig. 19) composed of a simple prehensile process, together with a three-jointed palp which terminates in three unequal curved claws. First pair of feet elongated, five-jointed; in the female directed downwards, apical portion like the palp of the second maxilla; in the male

much stronger, concealed within the valves, ending in three very long, and nearly equal curved setæ: in both sexes the basal joint bears a setiferous (branchial) lamina. Last pair of feet very small, two-jointed, reflexed, bearing two terminal setæ, one of which is very long, the other short. Caudal laminæ short, rounded, posterior margin bearing a series of curved spines, and on the middle of the anterior margin a single long and slender curved spine. Copulative organ of the male oblong, with entire apex.

1. **Conchœcia elegans**, G. O. Sars.

(Pl. lx., fig. 23; Pl. lxv., figs. 11–22.)

1865. *Conchœcia elegans*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 117.
1890. *Paraconchœcia gracilis*, . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 15.
1891. ,, ,, . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 66, pl. xii.

Shell of the female, seen laterally, elongated, sub-cuneiform, greatest height somewhat behind the middle and equal to less than half the length; rostrum large, and acutely pointed, with a subjacent, large, rectangular notch; dorsal margin straight, ventral moderately convex; posterior extremity much wider than the anterior, sub-truncate and almost rectangular, the lower angle rounded off. The valve of the right side is produced at the posterior dorsal angle into a short spine, which is armed on its upper margin with four small backward-pointing teeth. Seen from above the outline is narrow, ovate, greatest width behind the middle, obtuse in front, moderately pointed behind. Shell of the male somewhat more elongated, about thrice as long as high; rostrum sharper and more curved; posterior angle scarcely so prominent. Valves straw-coloured, marked with numerous closely-packed decussating striæ, the body of the animal showing through in deeply-coloured yellowish-brown patches.* Antennules of the female small and weak; those of the male (fig. 12) much larger, the first two joints large and muscular, the last two extremely small and bearing setæ very unlike those of the female, one of them being very short, another elongated, very thick, obtuse, and turned backwards in opposition to the antennule, the remaining three setæ long, slender, and nearly equal in length. In the male beyond the middle of the

* In spirit specimens, which alone we have had the opportunity of examining, the males are a deep vinous or brownish-red, the females opaque, yellowish or tawny-white. Prof. G. O. Sars says, "fulvo-rubido pigmentatum."

external seta there is ranged on each margin a short series of extremely delicate cilia (Pl. LX., fig. 23); these are very flexile, and are set for the most part nearly at right angles to the stem, resembling somewhat the patch of loose plumes at the base of the vane of a feather; these cilia are so small and delicate that they are often seen with difficulty, even with a magnifying power of 400 diameters. The basal joint of the antennule shows, irregularly scattered near its surface, a number of lenticular bodies overlying patches of red pigment, perhaps rudimentary visual organs* (Pl. LXV., fig. 12*a*.) Frontal tentacle in the female linear, in the male, dilated at the apex. Natatory branch of the antenna seven-jointed, the first joint more than twice as long as the remaining jointed portion; secondary branch bearing five apical setæ, of which in the female one is longer than the rest, while in the male (fig. 14), two are much elongated, one being thrice, the other four times as long as the shorter three; in addition to these setæ there is in the male a short sickle-shaped apical appendage. Male copulative organ (fig. 22) narrow, elongated, slightly dilated towards the apex, crossed by oblique transverse lines, and having an ejaculatory duct opening at its distal end. Length, 1·4 mm.

Habitat.—Taken abundantly by Dr. John Murray, in Loch Etive, Scotland, by the tow-net at a depth of 50 fathoms.

Distribution.—Rare in Drobak Fjord at a depth of 100–200 fathoms; very abundant among the Lofoten Islands down to 300 fathoms (G. O. Sars). This species is recorded by Dr. Claus (under the name of *Paraconchoecia gracilis*) as having been taken in a depth of 1500 metres, in lat. 37° 45′ N., long. 13° 38′ W.

2. **Conchœcia borealis**, G. O. Sars.

(Pl. LXI., figs. 9–19.)

1865. *Conchœcia borealis*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 119.

Shell of the female seen from the side, elongated, subquadrangular, higher behind than in front, greatest height equal to nearly half the length, dorsal margin straight, but showing a marked indentation near the middle, ventral slightly sinuated in the middle; anterior extremity gently convex, with a subacute rostrum of moderate size, and a slightly excavated sinus; posterior sub-truncate, rounded off below, and obtusely angulated above. Seen from above, elongate-ovate, about thrice as long as broad, widest near the middle, broadly rounded or sub-truncate in front, tapered and acutely-pointed behind. Surface of the valves densely cross-hatched with quadrangular reticulations (fig. 19) which are arranged

* These are called "ganglia" by Dr. Claus, but if they are purely nerve-centres it is difficult to understand the meaning of the red pigment-masses associated with them.

diagonally, the edges of the areas overlapping each other in a squamous fashion; supero-posteal angle of each valve armed with three or four rather large marginal teeth. Shell of the male somewhat narrower than that of the female. Length 3 mm.

Capitulum of the frontal tentacle acutely-pointed at the apex, slightly hispid in the female (fig. 15), scarcely dilated at the base; in the male (fig. 13) dilated and rectangularly truncate. Antennules of the female (fig. 12) as in the preceding species, in the male (fig. 13) bearing three long setæ, the first of which is considerably longer than the other two, geniculated beyond the middle, and bearing along the median portion of its posterior margin a series of closely set, simple, recurved, spine-like cilia (fig. 14); there are also two short, sensory filaments, of which the posterior is recurved and very much convoluted. Caudal laminæ (fig. 17), bearing on the anterior margin a single, long, slender spine, and on the posterior seven curved and finely pectinated spines, the posterior four much shorter than the rest.

Amongst the Lofoten Islands in a depth of 250–300 fathoms (G. O. Sars); Trondhjem Fiord, Norway, 150 fathoms (A. M. N.). Professor G. O. Sars remarks that he has found *C. borealis* only in one locality on the fishing bank of Lofoten, but that it was here tolerably abundant, and occurred in company with *C. elegans*, from which it was readily distinguished by its larger size, and by the form of the shell, notably by the sinuation of the ventral margin.

3. **Conchœcia maxima**, n. sp.

(Pl. lxi., figs. 1–8.)

Shell, seen from the side, subquadrangular, considerably higher behind than in front, greatest height scarcely equalling half the length; rostral prominence acutely pointed, with a rather deeply hollowed sinus beneath; anterior extremity well rounded away below, posterior truncated and widely rounded off below, obtusely angular above; dorsal margin almost straight, except for an abrupt depression near the middle; ventral very slightly arcuate; in the male the postero-dorsal angle of both valves bears a series of three teeth, the last of which is much thicker and larger than the others (fig. 1*a*). Seen from above, the outline is evenly ovate, about thrice as long as broad, extremities equal, sub-acute. The capitulum of the frontal tentacle (figs. 2, 3) is club-shaped, acutely pointed at the apex, and in the male dilated and truncated at the base; hispid with short, rather thickly set hairs. The stem of the antennule (fig. 2) shows, scattered through it in an irregular group, a number of dark red (? lenticular) bodies; and in the male the proximal long seta is armed throughout its middle third with a series of about

thirty closely-packed, short, recurved marginal spines (fig. 4). The secondary branch of the male antenna bears a thoroughly angulated, hooked appendage (fig. 5). Basal joint of the mandible palp not longer than the united lengths of the two following joints. Shell marked throughout with a not very conspicuous quadrangular reticulation (fig. 8). Spines of the caudal laminæ like those of *C. elegans*, but having fine marginal pectinations. Length of the female 3·6 mm.; of the male 3·15 mm.

We are indebted to Dr. John Murray, F.R.S.E., for specimens of this species, which were taken abundantly off Greenland, in lat. 74° 49′ N.; long. 11° 30′ W., in a depth of 350 fathoms, and by H. M. S. "Triton," in 1882, lat. 60° 20′ N.; long. 7·23′ W., in 200 fathoms, cold area, Faroe Channel.

Compared with *C. borealis*, which it very closely resembles, *C. maxima* is rather larger, and the shell is not so densely reticulated. The outline of the shell, seen dorsally, is different, and the spinules of the principal seta of the male antennule are considerably more robust.

4. **Conchœcia magna**, Claus.

(Pl. LXII., figs. 5–13.)

1874. *Conchœcia magna*, . . Claus, "Schriften zoologischen Inhalts: I. Die Familie der Halocypriden," p. 6, pl. i., fig. 6*c*; pl. ii., figs. 16, 18.

1887. ,, *tetragona*, . . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: IV. Ostracoda Mediterranea," p. 82, pl. xi., figs. 5, 6; pl. xiii., figs. 5–9.

1890. ,, *magna*, . . Müller, G. W., "Ueber Halocypriden," Zoolog. Jahrbücher, vol. v., p. 274, pl. xxviii., figs. 28, 29, 33, 34, 39, 40.

1890. ,, ,, . . Claus, Gattungen und Arten der mediterranen und atlantischen Halocypriden, p. 8.

1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans u. Mittelmeeres," p. 57, pl. ii., pl. iii., figs. 1, 2.

Shell of the female, seen from the side, oblong, subquadrangular, slightly higher behind than in front, the greatest height being equal to about half the length; dorsal margin nearly straight, ventral slightly sinuated in the middle; extremities very moderately rounded, postero-dorsal angle obtuse, not at all prominent;

rostrum wide, and moderately curved; sinus wide, and rather deep. The shell of the male is somewhat smaller and narrower, posterior margin almost rectangularly truncate, posterior dorsal angle prominent. Shell without any distinct sculpture, but very faintly marked with curved striæ. Length, 1·6 mm. (male); 1·8 mm. (female).

Capitulum of the frontal tentacle (fig. 6) in the male, destitute of hairs, rounded at its apex, curved and bent angularly on the stem; in the female (fig. 12) almost straight, slightly clubbed, but produced into a sharp point at the apex. Principal seta of the antennule of the male (fig. 7–7 *a*), bearing beyond the middle a patch of about twenty pairs of reflexed spinules, of which the proximal twelve are the longest, the distal seven or eight gradually decreasing in length to the last; the proximal sensory filament is about twice and a half as long as the distal one. Hooked appendage of the secondary branch of the right male antenna (fig. 8) angulated at the base, then bent abruptly, and forming a narrow arch; the three sensory filaments about half as long as the principal seta; in the female the principal setæ (fig. 13) are about one-fourth longer than the others; mamillary process of considerable size. Mandible-palp very stout, its proximal joint in the male scarcely so long as the three-jointed terminate portion, the first joint of which is as long or longer than the united lengths of the two following; terminal curved seta very strong, and bent in a subsigmoid fashion; the gland-vesicle extends through the three terminal joints:* biting-plate of the mandible strongly toothed. Endopodite of the foot-jaw scarcely two-thirds as long as that of the first leg. The long anterior seta of the caudal lamina (fig. 10) reaches as far as the tip of the first marginal claw; the seven pairs of claws are stout and moderately distant, one from the other.

Procured by A. M. N., when at the Zoological Station, Naples, in 1887.

Dr. Claus states that this species is widely distributed both at the surface and in the depths of the Mediterranean and Atlantic.

Some of the anatomical details given above are borrowed from Professor Claus's description, our own specimens not having been sufficient to enable us to verify them in every point.

* We have in no case been able to observe satisfactorily the curious glandular vesicles which are described minutely by Drs. Claus and Müller as existing beneath the shell and in other parts of the body of almost all the *Halocypridæ*. The prolonged preservation in alcohol of all our specimens has no doubt obliterated or obscured these organs.

5. **Conchœcia spinirostris**, Claus.

(Pl. LX., fig. 22.)

1874. *Conchœcia spinirostris*, . . Claus "Schriften zoologischen Inhalts. I. Heft., Die Familie des Halocypriden," p. 6, pl. i., figs. 1, 6*a*, 8; pl. ii., figs. 11, 14, 15.

1887. ,, *pellucida*, . . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: IV. Ostracoda Mediterranea," p. 80, pl. xi., figs. 1–4; pl. xii.; pl. xiii., figs. 1–4.

1890. ,, *spinirostris*, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 7.

1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 56, pl. i., figs. 1–12.

1894. ,, ,, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 237, pl. 6, figs. 1–9, 13.

Shell, seen laterally, oblong, pellucid, about twice as long as high; in the female, lower in front than at the feebly rounded hinder end; in the male, relatively higher, and with a straight posterior margin. Rostral sinus having a delicately serrated marginal membrane from which springs a fine bristle. Frontal tentacle of the female straight, slender, finely acuminate, that of the male angularly bent and clubbed at the capitulum. Principal seta of the male antennule scarcely longer than the adjacent ones, and having only eight or ten pairs of hooked marginal appendages (fig. 22) following which, but separated by wide intervals, are some hook-like processes of irregular size. The lower sensory filament is at least thrice as long as the upper. Hooked appendage of the secondary branch of the right male antenna strongly angulated. The five sensory filaments of the female antenna, with the exception of the very large principal seta, about equal in length. Proximal joint of the mandible-palp much elongated, longer than the three following joints. Ungues of the caudal laminæ curved only towards the points, and separated by considerable intervals from one another; the last four very small.

This species, according to Claus, is widely distributed at the surface in the Mediterranean, and has been taken also in the Adriatic at Trieste. The specimens described by G. O. Sars, under the specific name *pellucida*, were taken at Messina.

6. **Conchœcia striolata**, G. O. Sars.

1887. *Conchœcia striolata*, . . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," p. 84, pl. xiv., figs. 1–5.

Shell of the male subventricose; seen from the side rather narrow, oblong, twice as long as broad, lowest in front; dorsal margin slightly depressed in the middle, ventral forming a continuous curve with the anterior extremity; posterior margin rectangularly truncate, its upper angle prominent; rostral process horizontal, sinus wide, and almost rectangular. Valves not pellucid; everywhere distinctly marked with decussating striæ. Appendages almost exactly as in *C. magna*; ungues of the caudal laminæ, however, stronger, and densely ciliated behind. Length, 2·36 mm. Female unknown.

Messina (G. O. Sars).

7. **Conchœcia Haddoni**, n. sp.

(Plate lxiv., figs. 6–16.)

Shell of the female elongated, subquadrate, not much higher behind than in front, height equal to considerably less than half the length; anterior margin moderately prominent below the rostral sinus, which is rather wide and shallow; beak stout and acuminate at extremity; ventral margin evenly curved; dorsal somewhat sinuous, and obscurely crenated towards the hinder end; posterior subtruncate, rounded off below, and subangular, but not spinous dorsally. Shell surface for the most part striated, the striæ anastomosing irregularly at distant intervals (fig. 8), but within the antero-ventral, and, less distinctly, towards the postero-dorsal borders, closely reticulated with a small rhomboidal or pentagonal sculpture (fig. 7). Frontal tentacle of the female stout; capitulum (fig. 9) slightly curvate, slightly swollen at the base, and tapering to a narrowly rounded extremity, beset over the whole surface with short, distant, hair-like spinules; that of the male (fig. 10) similar, but very much more dilated at the base. The principal seta of the antennule in the male bears on its middle third a series of about thirty pairs (fig. 14) of very minute aculeate and reflexed spinules. Secondary branch of the antenna having a well developed narrow and subacute "mamillary" process, the distal prominence bearing two stout, short setæ; in the female there are five setæ, none of which are of the sensory kind, two of them long, the remaining three about half as long as the principal setæ. In the male (fig. 15)

there are two long ordinary setæ and three short sensory filaments; the hooked process is on the right side, strongly falcate, bent almost at a right angle, and slightly bulbous at the apex, where on the inner margin there is a series of minute hair-like crenulations (fig. 15 *a*); the hook of the left side is not so strongly arched, nor is it much dilated at the apex. The labium consists of two cushion-like eminences, which are thickly clothed with long flexuous hairs. Biting plate of the mandible (figs. 12, 13) armed with four very stout dagger-shaped lateral teeth, and at its base with a dense growth of hairs, which, in the female, are for the most part blunt and truncated, as if broken or shorn off in the middle. The caudal laminæ (fig. 16) are short and broad, with rather stout ungues, which increase successively in length from the first to the last, and are finely, but very distinctly, pectinated on their concave margins. Length of the female, 3 mm.; of the male, 2·55 mm.

We have seen only three specimens of this species. These occurred in a tow-net gathering made by Professor Haddon at a depth of 200 fathoms, 40 miles off Achill Head, Ireland.

8. **Conchœcia subarcuata**, Claus.

1890. *Conchœcia subarcuata*, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 9.

1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 58, pl. iii., figs. 3–9, pl. iv.

Shell almost twice as long as high; length, 1·8–2·1 mm.; height, 1–1·2 mm. Like *C. magna*, but more elongated, and with a more strongly arched ventral border, and a more curved rostral process. Frontal tentacle of the male with a club-shaped, dilated, almost rectangularly bent capitulum; that of the female angularly bent, with a long, dilated apex, which is produced into a strongly hooked point, and is beset on the lower border with fine spines. The antennules of the male have the terminal seta armed with about thirty pairs of closely set hooked processes, which are shovel-shaped at their bases.

This species is, according to Professor Claus, very like *C. magna*, and was taken in a depth of 1500 mètres in lat. 37° 45′ N.; long. 13° 38′ W.; also in 500 mètres at Funchal, and at the surface of the Atlantic Ocean, on December 1st, 1887.

9. **Conchœcia bispinosa**, Claus.

1890. *Conchœcia bispinosa*, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 10.

1891. „ „ . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 59, pl. v.; pl. vi., fig. 1; pl. viii., figs. 7, 8.

Shell elongated, twice as long as high, each valve with a short, strong, spinous prominence at the postero-dorsal angle; rostral process short and broad. Length of the shell, 1·5–1·8 mm.; height, 0·8–0·9 mm. Capitulum of the frontal tentacle in the female (as well as in the male) clubbed, angularly bent, and beset with numerous small spines. Terminal seta of the antennule in the male bearing about thirty pairs of closely set barbed hooks. Proximal sensory filament thrice as long as the distal one. Principal seta of the secondary branch of the natatory antenna, in the female, long and powerful, more than one-third longer than the longest of the sensory setæ. In the male the three sensory setæ are very slender; the hooked process is bent into an irregular curve, and on the left side is very strongly developed; one of the two lateral setæ much elongated.

Found at a depth of 1500 mètres in lat. 37° 45′ N.; long. 13° 38′ W.; also in surface-gatherings at Funchal (Prof. Claus).

10. **Conchœcia hyalophyllum**, Claus.

1890. *Conchœcia hyalophyllum*, . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 11.

1891. „ „ . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 60, pl. vi., figs. 2–10; pl. viii., fig. 9.

Shell rather short; height equal to about three-fifths of the length, nearly quadrangular, extremely thin and pellucid, much compressed laterally; rostrum large and curved. Length, 1·5 mm.; height, 0·9 mm.

Frontal tentacle of the female slender, elongated, with very long, angularly bent extremity, which bears on the upper margin a few spine-like hairs, and on the under side two rows of the same. Capitulum of the tentacle in the male shorter, broadly club-shaped, irregularly armed with spinous hairs. Terminal seta of the male antennule bearing about twenty pairs of slender, thickly-set spines, and not longer than the two neighbouring setæ; proximal sensory seta

thick and very long, almost as long as the antenna, in the female twice and a-half as long as the four sense-setæ. The principal seta of the secondary branch of the female antenna is scarcely longer than the longest of the four adjacent setæ. The hooked appendage of the right antenna of the male is bent to a right-angle at the base.

This species is recorded by Claus from Ischia at a depth of 900 mètres; from the Atlantic, lat. 34° 18′ N., long. 15° 34′ W., depth 1000 mètres, and from the surface of the sea at Orotava.

11. **Conchœcia porrecta**, Claus.

1890. *Conchœcia porrecta*, . . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 12.

1891. ,, ,, . . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 61, pl. vii.

Shell elongated, twice and a-half as long as high; dorsal margin incurved; posterior rather strongly convex; rostrum rather short; no spine at the postero-dorsal angle. Length, 1·6 mm.; height, 0·65 mm. Frontal tentacle of the female slender, straight and elongated, slightly dilated at the apex, and suddenly tapering to an acute point; in the male the capitulum is broadly clubbed, much stouter than the peduncle, and bent at an angle. Terminal seta of the male antennule armed with from forty to fifty pairs of hooklets, of which the fourteen or sixteen distal pairs are the stouter, and more closely packed; those towards the base being simple spine-like hairs, and set at wider intervals. Hooked appendage of the right antenna of the male bent at an oblique angle. Setæ of the secondary branch of the female antenna short and slender; the principal seta not much longer than the four sensory organs.

Numerous examples of both sexes were found by Dr. Claus in the Atlantic, from Cape Finisterre to Teneriffe, in depths varying from 1000 to 1600 metres.

Conchœcia obtusata, G. O. Sars.

(Pl. lxiii., figs. 1, 2.)

1865. *Conchœcia obtusata*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 118.

1890. *Halocypris obtusata* . . Sars, G. O., "Oversigt af Norges Crustaceer. ii. Branchiopoda, Ostracoda, Cirripedia," p. 53.

Shell of the female seen from the side, elongate-ovate, equal in height before

and behind, greatest height somewhat less than half the length and situated in the middle; superior margin nearly straight; inferior moderately arcuate; posterior extremity obtusely rounded, prominent in the middle, obtusely angulated above, rounded off below; anterior extremity more than usually prominent below the rostrum, which is sub-acuminate and deflexed, antennal sinus narrow and directed forwards. Seen from above the outline is almost equally broad at both extremities, greatest width much less than the height, and equal to about one-third of the length, extremities obtusely acuminate. Valves delicately striated (Sars), but not reticulated; colour, pale yellowish. Frontal tentacle sublanceolate, capitulum more dilated than that of *C. elegans*. Antennules as in *C. elegans*. Swimming branch of the antennæ eight-jointed, the last joint very small. Caudal laminæ small, like those of *C. elegans*, except that the seven claws gradually decrease in length backwards. Male unknown. Length of the female, 2 mm.

Very rare at the head of the Fekke Fiord, Norway, in rather shallow water; and in Trondhjem Fiord in 40–50 fathoms.

Professor Sars has kindly supplied us with a few specimens of this very scarce species, but not in a condition to allow of their being accurately figured or of the soft parts being fully made out. We have therefore transcribed his original description, giving only two outline figures drawn from the best preserved of our specimens. The second figure does not quite accurately agree with the description of Professor Sars, but this may perhaps arise from a slight gaping of the valves.

In a more recent work Sars has expressed the opinion that this species ought to be transferred to the genus *Halocypris*, a view which we are unable to adopt, as it seems to diverge in many important points from the character of that genus, as indicated by himself and Dr. Claus.

The shell is not very short nor rounded, nor is the rostrum particularly short or obsolescent as in *Halocypris*; the female antennules agree with those of *Conchœcia*; the basal parts of the antennæ and of the mandible-palps are as long as those of the similar organs in *Conchœcia*, and not very short as they ought to be in *Halocypris*. Lastly, a striking character given by Dr. Claus as belonging to *Halocypris* is here absent, namely, the lancet-shaped dilatation of the principal seta of the secondary branch of the antenna.

Genus 2. Paraconchœcia, Claus.

Shell scarcely different from that of *Conchœcia*, but very delicate, much compressed, and usually furnished with a spinous projection at the hinder end of the right valve; chewing portion of the mandible forming a triangular-toothed plate, which extends over the entire width of the limb, the four hooked teeth depressed towards the side, and enveloped in a more or less dense tuft of setæ.

Paraconchœcia oblonga, Claus.

1890. *Paraconchœcia oblonga*, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 13.

1891. „ „ . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 63, pl. viii., figs. 10, 11; pl. ix.

Shell elongated, with three or more teeth on the inner line of the anterior margin, and a spinous process at the postero-dorsal angle of the right valve. The shell of the male is twice, and of the female, twice and a-half as long as high. Length, 1·4–1·5 mm.; height, 0·6–0·7 mm. Frontal tentacle broadly clubbed at the extremity; in the female angulated, and pointed at the apex; in the male rounded at apex, terminal portion aculeated on the margin. Terminal seta of the male antennule much elongated, beset with numerous pairs of long, spine-like hairs; distal sensory seta rudimentary; in the female the terminal seta is likewise beset with spines, and is nearly double as long as the four sensory setæ. Hooked appendage of the secondary branch of the right male antenna sharply bent, but without any well-marked angle; in the female the principal seta of the secondary branch exceeds the four equal sense-organs by about half their length.

In lat. 37° 45′ N., long. 13° 38′ W., and lat. 34° 18′ N., long. 15° 34′ W., both at the surface and in the depths of the sea (Claus).

Paraconchœcia spinifera, Claus.

1890. *Paraconchœcia spinifera*, . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 14.

1891. „ „ . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 64, pl. x.

Shell elongated, twice as long as high, very thin and delicate. Length, 1·8–2 mm.; height, 0·85–0·9 mm. The postero-dorsal angle of the right valve bears two spines, one smaller than the other. Frontal tentacle long and slender, its terminal portion short and stout, and beset with hairs on the ventral margin, the apex produced into a hooked point; in the male the tentacle is as in *P. oblonga*. Terminal seta of the male antennule armed with a very large number of spines. Hooked appendage of the secondary branch of the right antenna of the male bent to an acute angle near the base; in the female the four shorter setæ of the

secondary branch of the antennæ are of nearly equal length, and about two-thirds the length of the principal seta.

Dr. Claus records the occurrence of this species at Capri and in the Atlantic; lat. 34°, 18′ N., long. 15° 34′ W.

Genus 3. Conchœcetta, Claus.

Shell much elongated, in the female about thrice as long as high, hinder margin meeting the ventral obliquely, without sculpture, without hinge-teeth; glands of the dorsal margin wanting. Tooth ridges and chewing-edges of the mandible separate, both portions toothed on their free edges, the four hooked teeth largely developed.

1. **Conchœcetta acuminata**, Claus.

1890. *Conchœcetta acuminata*, . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 16.

1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 67, pl. xiii. and pl. xiv.

Dorsal margin of the shell much longer than the ventral, and terminating in a spinous process, not always found on both valves. Rostrum in the female acutely pointed, in the male rounded off. Length of female, 3·2–3·4 mm.; male, 2·3–2·4 mm.; height of female, 1·2 mm. Frontal tentacle of the female straight and elongated, very slender, acuminate at the apex; that of the male stout, bowed, and bent at a right angle. Antennules of the female (exclusive of setæ) reaching scarcely more than half the length of the tentacle; terminal seta beset with hairs, and almost three times as long as the four sub-equal adjacent setæ. In the male the antennules reach as far as to the bend of the tentacle, the terminal seta bearing twenty-four pairs of rectangularly bent, hook-like spinules, the two adjacent setæ about equally long.

In depths of 500 to 1000 mètres from the following Atlantic stations:—off Cape Finisterre, between Teneriffe and Grand Canary; and in lat. 34° 18′ N., long. 15° 34 W.; also at the surface in the neighbourhood of Puerta Orotava.

Genus 4. Conchœcilla, Claus.

Shell much elongated, gaping, without hinge-processes, with a long, acute rostral prominence, and a long spine-like prolongation of the hinder extremity; surface marked more or less with diagonal ribs or reticulations; a patch of gland-cells near the ventral margin of the right valve; instead of the group of gland

cells at posterior angle of right valve there is a similar group near the front of its ventral margin; the dorsal gland-cells are wanting, but there are groups of such sacs (two on the right valve and three on the left), close to the posterior spinous extremity of the shell; abdomen conically elongated; armature of mandible as in *Conchœcia*, but with an unusually large transverse toothed ridge, and four long curved teeth.

The few specimens which we have seen, belonging to this genus, were in poor condition, and did not admit of our verifying some of the characters ascribed to it by Dr. Claus, more particularly those relating to the gland cells, which we have not seen. But the very characteristic and remarkably formed shell is of itself sufficient to constitute a good generic feature.

1. **Conchœcilla daphnoides**, Claus.

(Pl. LXIV., fig. 22.)

1890. *Conchœcilla daphnoides*, . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 18.
1891. ,, ,, . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 68, pl. xv.

Shell almost flat dorsally, much elongated, height very small, but valves outstretched and almost wing-like; ventral margin arched, bending upwards behind, and meeting the dorsum at an acute angle; anterior margin narrow, convex, and forming a sharply angular sinus at its junction with the long rostrum, which is longer on the left valve than the right; each valve bears at the long, pointed, posterior extremity a series of marginal spinules, the right valve being a good deal the longer of the two. Length, 2·85 mm.

We found a single specimen of this species amongst material taken by Professor Haddon in the deep tow-net (200 fathoms) 40 miles off Achill Head, Ireland. This specimen we have here figured, but our descriptive details are taken from Dr. Claus's monograph.

Distribution.—Young specimens were taken by Claus in lat. 37° 45′ N., long 13° 38′ W., and in lat. 34° 18′ N., long. 15° 34′ W.

2.—**Conchœcilla lacerta**, nov. sp.

(Pl. LXII. fig. 1–4; LXV., fig. 1–10.)

Shell, seen from the side, much compressed and greatly elongated; greatest height situated in the middle, and equal to one-fifth of the length; anterior

extremity produced into a very long, slightly curved, slender, acutely pointed rostrum, at the base of which is a distinct, though shallow sinus, which passes at a right angle into the narrow anterior margin; the posterior extremity is formed by a long spine-like projection, which is wide at the base, and acutely pointed behind, rectilinear above and continuous with the dorsal margin below, passing by a gentle curve into the ventral margin; dorsal margin slightly curved towards the front, having a distinct median indentation, but otherwise almost straight; ventral gently and evenly arcuate as far as its juncture with the posterior spine; margins of the valves entire, except round the produced posterior extremity, which is armed, especially on its ventral edge, with numerous adpressed, backward-pointing spines. Surface of the shell marked, chiefly toward the hinder extremity, with faint decussating striæ, which form a scale-like reticulation. Seen from above, the outline is much compressed, width and height about equal, produced in a cuneate fashion in front, and into a long attenuated spine behind. The antennule bears in the female (Pl. LXV., fig. 5) one long terminal seta, and four very short sub-equal sensory filaments; in the male (Pl. LXII., fig. 1), are three long setæ, the proximal one being much longer than the rest; two very short, straight filaments, and a third, which is hook-like and curved backwards; the long, proximal seta is beset from the middle nearly as far as the base, with a series of very fine, closely packed, recurved hairs (Pl. LXII., fig. 2). Frontal tentacle in the female very slightly clubbed, a little hispid, its tip slightly produced and pointed; in the male the capitulum is curved, blunt, and slightly bulbous at the apex, dilated and truncated at the base. The basal joint of the secondary branch of the antenna in the male (Pl. LXII., fig. 3) has an angularly-bent hook. Basal joint of the mandible-palp (Pl. LXV., fig. 7) about equal in length to the three following joints. Apical setæ of the first foot (Pl. LXV., fig. 8) in the female nearly equal: the last foot (Pl. LXV., fig. 10) has one very long seta, and another about half as long. Length, 4·73 mm.

Of this remarkable species we have seen only two or three specimens, which were taken by Dr. John Murray, in H. M. S. "Triton," in 1882, lat. 60° 31′ N.; long. 7° 34′ W., in 580 fathoms; and in lat. 60° 20′ N., long. 7° 55′ W., in 200 fathoms, these stations being in the cold area east of the Faroe ridge in 200 fathoms, August 20, 1882. The size of the specimen and their general configuration lead to the suspicion that they may, perhaps, belong to the adult form of *C. daphnoides*, of which species no fully grown specimens have (as Dr. Claus thinks), yet been seen. But without further evidence we should scarcely be justified in uniting the two forms under one specific name.

Genus 5. **Conchœcissa**, Claus.

Rostral process beak-like, long, sharp and strongly curved; sinus moderately large; hinder extremity of each valve produced dorsally into a backward-pointing sharp spine, and ventrally into a rounded or obtusely-pointed spine. Shell distinctly striated, and towards the free margins strongly reticulated; ventral margin more or less roughened with minute projecting spines; mandible with well-developed tooth-ridges and four large lancet-shaped spines.

1. Conchœcissa, **armata**, Claus.

(Pl. lxiv., figs. 1–5.)

1890. *Conchœcissa armata*, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 19

1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 70, pls. xvi., xvii., xviii.

Shell elongated, lower in front than behind, greatest height equal to less than half the length; seen from the side the outline is sub-quadrate, rectangularly truncate behind, ventral margin rather protuberant; striation of the shell well marked, the ventral and anterior portions strongly reticulated with transverse rows of elongated sub-quadrate areas, which towards the postero-dorsal angle become nearly square, and in the central area almost give place to the longitudinal striæ. Rostrate process large, very acute at the apex, at first directed straight forwards, afterwards slightly curved downwards; lower margin of the antennal sinus well arched forwards, leaving a slight hollow at its junction with the base of the rostrum. Infero-posteal corner produced into a conspicuous acute spine-shaped process, that of the right valve being longer than that of the left; infero-posteal corner also produced into a blunt, spine-shaped process, which, however, is not so large as the dorsal spine. The lower border of this process is represented by Claus as serrated, but it is not so in our specimen. The chief peculiarity of this structure is that it is not a production of the edge of the valve, but takes its origin at some distance within the border (Pl. lxiv., fig. 1). Frontal tentacle of the female (fig. 3), much longer than the antennule, capitulum slender, only slightly club-shaped, and having a few small marginal spinules; in the male the organ is much shorter, the capitulum distinctly clubbed, and bent at a right angle to the peduncle. The principal seta of the antennule of the male bears eight or nine pairs of unusually strong hooklets. The setæ and

sensory filaments of the secondary branch of the antennæ are very long, and the mamillary prominence is large and tooth-like; in the male the prehensile hook of the right side is rectangularly bent at the base, and curved beyond; on the left side simply hooked; the mamillary process slightly hooked. Teeth and general armature of the mandibles (figs. 4, 5) strongly developed. The long posterior seta of the caudal lamina is pectinated with short, fine cilia; the seven marginal ungues increase progressively in length from the first to the last, and are smooth and somewhat widened at the base, pectinate beyond. Length of the shell 3 mm. (female).

Tow-net, "Triton" Expedition, lat. 60° 20′ N., long. 7° 53′ W., in 200 fathoms, 20th August, 1882, in the cold area of the Faroe channel (Dr. J. Murray). In a depth of 1000 mètres, lat. 34° 18′ N.; long. 15° 34′ W.; 500 mètres, lat. 32° 30′ N.; long. 16° 42′ W. (Claus).

Dr. Claus doubtfully identifies this species with *Halocypris imbricata* of the "Challenger" Ostracoda Report, but a comparison of specimens (females only), scarcely bears out this opinion, though the resemblance is certainly very close.' The mandibular teeth of the two forms seem to be slightly different, and the natatory antennal setæ of *H. imbricata* are very conspicuously plumose, while in *C. armata* they are quite simple. The size of *C. imbricata*, also, is greater, being 3·6 mm. for the female, and 4 mm. for the male.

The foregoing description, so far as the male is concerned, is taken from Dr. Claus; the only specimen which we have seen is a female.

Genus 6. Mikroconchœcia, Claus.

Shell compressed, of small size, and with a striated or reticulated sculpture of the outer surface; anterior margin prominent, dorsal margin without any posterior projection. Hinge well developed, a tooth on the left, and a hollow on the right valve. The hooked lateral teeth of the mandible are strengthened by a strong chitinous plate (Claus), and there is a marginal bearded line of cilia and short bristles. Proximal sensory filaments of the antennæ of the male furcate; in the female, most, if not all of them, are once or twice forked.*

Mikroconchœcia Clausii, G. O. Sars.

(Pl. lxiii., figs. 3–9.)

1865. *Halocypris* sp., . . . Claus, "Ueber die Geschlechts differenzen von Halocypris," Zeitschrift für Wissensch. Zoologie, Bd. xv., Taf. xxx. (*fide* Claus).

* Claus says that all except one are furcate, but we have not made this out clearly.

1887. *Halocypris Clausii*, . . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," p. 87, pl. xi., figs. 7–10; pl. xiv., figs. 6–18.

1890. ,, ,, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 22.

1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 73, pl. xx.

1894. *Conchœcia Clausii*, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel.," p. 230, pl. vi., figs. 21, 23–30; pl. viii., figs. 31, 32.

Shell of the female, seen laterally, broadly sub-ovate, very short and high; length not much greater than the height; dorsal margin almost straight, ventral evenly, and boldly convex, and forming a continuous curve with the anterior and posterior margins; rostrum rather large, curved and prominent; sinus of moderate size; anterior extremity curved, rather prominently arched below the sinus, slightly narrower than the posterior, which is sub-truncate, very boldly rounded at its junction with the ventral margin and not at all produced at the obtuse dorsal angle. Seen from above, the outline is broadly ovate, widest behind the middle; width considerably more than half the length. Shell of the male rather narrower; seen from above, widest towards the front (Sars). Surface of the valves strongly reticulated. Length of the female ·78 mm.; of the male ·72 mm. Frontal tentacle of the female (fig. 7) not reaching beyond the extremity of the limb, nearly straight, capitulum obtuse; that of the male much longer than the limb; capitulum curved, spoon-like, dilated at the base. Antennules of the female small, imperfectly jointed, the sensory setæ sub-equal, furcate; antennules of the male (fig. 5) five-jointed, the two basal joints very stout, the rest very small; the proximal sensory filament is about as long as the second joint of the antennule and furcate; the distal filament simple and about half as long as the other; of the three long setæ the distal one bears on its inner margin a series of (seven to fourteen, Claus), small button-like nodules (fig. 6) which are set in a single row and wide apart. Hooked appendage of the antennæ (fig. 8), strongly bent and thickened towards the base. The male copulatory organ (fig. 9) has the distal half of its posterior margin annulated. The other organs present no special diagnostic characters.

Capri; Las Palmas, 450 mètres; Funchal, 500 mètres (Claus); Messina (G. O. Sars); Naples (A. M. N., and G. W. Müller).

Sub-fam.—**Halocyprinæ.**

Shell short, ventricose, scarcely longer than high; rostral process short, sinus obsolete, presenting only a slight sinuation of the valve. Frontal tentacles alike in both sexes; capitulum club-shaped, bent at an obtuse angle on the peduncle. Peduncle of the antennule angularly bent, setæ flexuous; in both sexes one long terminal seta, and four short equal sensory ones. Secondary branch of antenna without mamilliform prominences; setæ of the swimming branch plumose, and nearly twice as long as the peduncle. Basal joint of the mandible-palp short, not longer than the second joint, its biting-plate produced, and "shovelshaped." First and second pairs of maxillæ short, and nearly equal. In the male the first maxilla is like that of the female both in size and shape, and the terminal setæ do not form an elongated lash.

Genus 1. Halocypris, Dana (*ex parte*).

Rostral process short, right valve prominent in front; rostral sinus inconspicuous; ventral margin strongly convex; a hinge-joint, consisting of a tooth on the left and socket on the right valve at the anterior extremity; hinge of hinder end scarcely developed. Free edge of the valves strongly rounded and thickly beset with gland-cells. Principal seta of the secondary branch of the antenna dilated and lancet-shaped at the end. Mandible without a crenulated pad and accessory teeth, but having a broad conical process directed towards the apex of the limb.

1. **Halocypris concha**, Claus.

(Pl. lxii., figs. 14–19.)

1874. *Halocypris concha*, . . Claus "Schriften zoologischen Inhalts: 1. Die Familie der Halocypriden," pl. ii., figs. 20–25; pl. iii., figs. 26–35.

1890. „ „ . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 24.

1891. „ „ . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 77, pl. viii., fig. 12; pl. xi., figs. 6, 7; pl. xxii., figs. 1–12; pl. xxiv., figs. 6–20; pl. xxvi., fig. 1.

1890. „ *dubia*, . . Müller, G. W., "Ueber Halocypriden," Zoologischen Jahrbüchern, vol. v., p. 269, pl. xxviii., figs. 19, 23, 24, 30, 35: var. *major*.

Shell marked with delicate, more or less distinct concentric lines, which are here and there arranged crosswise. Length about 1·8 mm.; height, 1·4 mm.

Capitulum of the frontal tentacle long (fig. 15), subsigmoid in shape. Terminal seta of the antennule nearly twice as long as the four sensory filaments. Basal joint of the main branch of the antenna about twice and a-half as long as the apical, short-jointed portion, which is provided with very long plumose swimming setæ; principal seta of the secondary branch dilated and fusiform towards the apex, only slightly longer than the neighbouring seta, which is about twice as long as the remaining three equal setæ. Hook of the secondary branch of the left male antenna (fig. 16) broadly curved. Of the three terminal setæ belonging to the first and second maxillæ, two are curved, and nearly equal in length, the third shorter and more slender. Marginal spines of the caudal laminæ (fig. 19) elongated, slender, and slightly curved.

A few specimens occurred in tow-net gatherings taken by the "Challenger" expedition, but were not recognized nor described by Dr. Brady in his Monograph of the Ostracoda. These were from the following stations:—Lat. 35° 18′ N.; long. 147° 9′ E.*; and lat. 32° 41′ N.; long. 36° 6′ W.; lat. 35° 41′ N.; long. 157° 41′ E. Dr. Claus gives "Atlantic Ocean" merely as the habitat of this species, and Dr. G. W. Müller does not seem to be any more precise in his record.

Though we do not doubt the identity of our specimens with *Halocypris concha*, Claus, it should be noted, that the reticulated ornament of the shell is somewhat more prononnced than that described by Dr. Claus. Owing to paucity of material we have had to adopt, for the most part, Dr. Claus's description of the species.

2. **Halocypris pelagica**, Claus.

1890. *Halocypris pelagica*, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 25.

1890. ,, *dubia*, . . Müller, G. W., "Ueber Halocypriden," Zoologischen Jahrbüchern, vol. v., p. 269, pl. xxviii., figs. 19, 23, 24, 30, 35; var. *minor* (*fide* Claus).

1891. ,, ,, . . Claus, "Die Halocypriden des atlant. Oceans und Mittelmeeres," p. 78, pl. xxi., figs. 1–11.

Length of shell, 1·1–1·4 mm.; height, 0·9–1·1 mm. Frontal tentacle proportionately thicker and shorter than in the preceding species, capitulum

* It should be mentioned that the inscribed date on this gathering has become partially illegible, and the locality may therefore be erroneous.

shorter, and scarcely bent. Antennules more strongly curved, twice bent in a rectangular manner; terminal seta nearly twice as long as the four sensory setæ. Peduncle of the natatory branch of the antenna about twice as long as the short-jointed distal portion, which bears long plumose setæ: principal seta of the secondary branch greatly dilated, and about one-third longer than the next seta, which is again double the length of the remaining three; hooked appendage of the male bent upon itself abruptly at the base.

Taken at the surface, and in various depths, as follows:—Off Cape Finisterre, in lat. 37° 45′ N., long. 13° 38′ W.; lat. 34° 18′ N.; long. 15° 34′ W.; lat. 32° 30′ N.; long. 16° 42′ W.; off Funchal (Claus).

Genus 4. **Halocypria**, Claus.

Shell almost globular, with small but distinct rostrum, and deep sinus. Hinge at hinder end well-developed. Principal seta of secondary branch of antenna very long, filiform, not dilated nor lancet-shaped. Mandible bearing, in addition to the transverse rows of teeth, a group of four strong curved teeth near the base. First pair of legs short and stout, almost conically pointed.

The characters which, according to Claus, chiefly distinguish the shell of this from the preceding genus are the larger development of the posterior hinge-processes, the more pronounced rostrum and deeper sinus, together with the presence, on the anterior border of the right valve, of a considerable prominence, and on the left valve two smaller prominences.

1. **Halocypria globosa**, Claus.

1890. *Halocypria globosa*, . . Claus, "Die Gattungun und Arten der mediterranen und atlantischen Halocypriden," p. 25.
1890. ,, ,, . . Müller, G. W., "Ueber Halocypriden," Zoologischen Jahrbüchern, vol. v., p. 270, pl. xxviii., fig. 20.
1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 79, pl. xxii., figs. 13–18.

Shell almost spherical, with delicate longitudinal striations on the dorsal surface; hingement consisting of a tooth and fossa strongly developed at the hinder end. Frontal tentacle elongated, with a long deflexed capitulum

Peduncle of the principal branch of the antenna twice and a-half as long as the short-jointed apical portion, which has plumose swimming setæ, setæ more than half as long again as the limb itself, the principal seta of the secondary branch is more than twice as long as the sensory filaments. Caudal laminæ bearing seven pairs of curved spines. Length, 2·2 mm.; height, 1·8 mm.; width, 1·6 mm.

Atlantic Ocean; taken at the surface, and in various depths (Claus); Gibraltar (Chierchia, *fide* G. W. Müller).

A single specimen was noticed amongst the "Challenger" captures, but the exact locality is doubtful. The male of this species has not yet been seen.

Our description is taken in part from that given by Dr. Claus; the one specimen which we have had the opportunity of examining being imperfect.

Section III.—**Cladocopa**, G. O. Sars, 1865.

Fam.—**POLYCOPIDÆ**, G. O. Sars.

Shell round, or nearly so, valves thin, sub-equal, without the antennal sinus usually found in Myodocopa. Antennules and antennæ adapted for swimming, both with large muscular basal joints, and long terminal setæ; the former not branched nor geniculated; the latter biramose, both branches natatory. Mandibles distinctly toothed, furnished with a palp, which is not pediform, ending in setæ, not in ungues. Only two pair of limbs behind the mandible, and these formed for swimming, the first with one very minute seta-bearing lobe on the basal joint, and a long laminar appendage attached to the antepenultimate joint; the second of these limbs is much smaller then the first, its three-jointed basal joint wide and expanded on one side into a seta-edged branchial plate. Caudal laminæ broad and rather short, their hinder margin bearing a series of ungues. No eyes. No heart. Intestine forming a simple sac.

Genus Polycope, G. O. Sars, 1868.

Shell nearly round, texture thin and fragile, corneous, and only slightly calcareous. No frontal tentacle, but in its place two short ciliated setæ. Antennules (Pl. lxvii., fig. 1) three-jointed, terminating in very long setæ. Antennæ (Pl. lxvii., fig. 2) with the branches sub-equal in length, the larger branch similar in structure to the natatory branch in Cypridinidæ, nine-jointed, and bearing lateral and terminal swimming setæ, the other branch three-jointed ending in a bunch of setæ. Mandible (Pl. lv., fig. 13) with a masticating toothed lobe, palp two-jointed, the first joint strong, and furnished above with a small

seta-tipped laminar appendage, second joint with lateral and terminal setæ. Incisive portion of the first maxilla (Pl. lxvii., fig. 3) forming a small unguiferous and setiferous lobe, and bearing a very large four-jointed palp, from the second joint of which springs a large laminar appendage, which together with the palp itself is densely setiferous at the apex. Second maxilla (Pl. lv., figs. 14, 15) three-jointed, first two joints very massive, last slender, and giving origin to a single stout apical seta; to the basal joint is attached a semi-elliptic, seta-edged branchial plate. Caudal laminæ (Pl. lv., fig. 16) having the ungues set in deep incisions of the margin, which is projected between the bases of the ungues in conspicuous processes.

Polycope orbicularis, G. O. Sars.

(Pl. liv., figs. 9, 10; Pl. lv., figs. 12–16; Pl. lxvii., figs. 1–3.)

1865. *Polycope orbicularis*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 122.
1868. ,, ,, . . Brady, "Monog. Recent Brit. Ostr.," p. 471, pl. xxxv., figs. 53–57.
1874. ,, ,, . . Brady, Crosskey, and Robertson, "Monog Post-Tertiary Ostracoda," p. 219, pl. xii., figs. 22, 23.

Shell of the female, seen from the side almost circular, greatest height situated in the middle, and nearly equal to the length, posterior extremity well rounded, anterior narrower, and slightly exserted, dorsal margin strongly arched, almost angulated in the middle, ventral evenly and rather boldly arched; seen from above the outline is broadly sub-rhomboidal, widest in the middle, the width equal to considerably more than half the length, extremities equal and obtuse. Surface of the valves covered with closely-set small circular impressed puncta, and marked with a polygonal reticulated pattern, the ventral margin fringed with small sharp spines or setæ. Colour yellowish, mottled with reddish spots or patches.

Antennules (Pl. lxvii., fig. 1), three-jointed, basal joint very massive, pyriform, front margin finely ciliated, and bearing one small seta, second and third joints small, especially the last, the penultimate with one small terminal seta, the last having five setæ, which exceed in length the whole limb. Antennæ (Pl. lxvii., fig. 2) with the basal joint very broad and massive, chief natatory branch nine-jointed, basal joint without seta, shorter than combined length of following joints, remaining joints broader than long, joints 2–8 each with one long natatory

seta, last joint with two somewhat shorter terminal setæ; the second branch has the first joint naked, much surpassing the length of the two remaining joints, which are very short, and furnished with a terminal bunch of long setæ. The mandible (Pl. LV., fig. 13) has the biting process divided into five teeth, palp two-jointed, the first bulbously swollen on the inner margin, which bears four setæ, its outer margin furnished with a small bisetose laminar appendage; the last joint has three setæ on its inner margin and four at the apex. First maxilla (Pl. LXVII., fig. 3) composed of a short and broad setiferous lobe with a very large four-jointed palp; the maxillary lobe bears several plumose setæ and a papilla, from which spring two large and one small unguiform setæ; basal portion of the palp very stout, its first joint much broader than long, and bearing on its inner margin a fascicle of seven or eight plumose setæ; second joint about twice as broad as long, giving attachment on its distal margin, internally to two plumose setæ, and externally to a large one-jointed laminar appendage, which reaches as far as the extremity of the limb, has three setæ near the middle of its outer edge, and at its obliquely truncated apex nine very long and slender ciliated setæ; the third joint of the palp is much less stout than the preceding, and has a single stout plumose seta on its inner edge; terminal joint short, obliquely truncated at the apex, and bearing seven plumose setæ, the innermost of which is much longer than the rest. Second maxilla (Pl. LV., figs. 14, 15) three-jointed, two lower joints broad, the first being ciliated on its lower margin, which also bears one small distal seta; to its front margin is attached a semi-elliptic branchial plate, edged with setæ; second joint also having the lower margin finely ciliated, on each margin towards the extremity a densely ciliated seta, and at the extremity five densely ciliated but not long setæ; last joint very narrow and small, nearly thrice as long as broad, but only sufficiently wide to support the one short densely ciliated and somewhat unguiform seta, in which the limb ends. Caudal laminæ (Pl. LV., fig. 16) deeply incised for the reception of each of the eight somewhat spiniform ungues, which are ciliated on their inner margins and not conspicuously dilated at their base; the ungues progressively increase in length from the first to the last, and the intercurrent projections of the caudal laminæ are broadly triangular in form, with sub-truncate apices, except the last, which is chisel-shaped, sharp at the apex, and twice notched on its anterior margin. Length of female ·63 mm.; male unknown.

Habitat.—Besides the localities enumerated in the "Monograph of recent British Ostracoda," we have records of the occurrence of *P. orbicularis* in the following places:—Loch Fyne; Cumbrae, 16 fathoms; Rothesay and Kilchattan Bays; Clew and Birtirbuy Bays; Lough Swilly; off Valentia, 112 fathoms; New Grimsby Harbour, Scilly Islands, and at several points off the coasts of Durham and North Yorkshire.

Distribution.—In many places on the Norwegian Coast (G. O. Sars).

The surface-sculpture of this species is variable, and tends to become obsolete altogether in old and thick specimens; the reticulated pattern being visible only in what seem to be comparatively young specimens. Professor G. O. Sars notes that the motions of the animal are very lively and much resemble those of some of the Lynceidæ such as *Chydorus;* and this we are able to verify from our own observation. He also says that it is found chiefly in places where the bottom is covered with a thin layer of mud, and this accords fairly well with our own experience.

2. **Polycope punctata**, G. O. Sars.

(Pl. lxvii., figs. 9–12.)

1869. *Polycope punctata*, . . Sars, G. O., "Nye Dybvandscrustaceer fra Lofoten" (Vidensk. Selsk. Forhand.), p. 27 (separate copy).

"Shell, seen from the side, almost circular, scarcely at all produced in front, the margins more evenly rounded than in *P. orbicularis*. Seen from above, rather tumid, the greatest width much exceeding half the length; valves thickly beset with minute depressed puncta, but only very slightly reticulated; colour very pale green."—(G. O. Sars.)

Basal joint of the antennule (fig. 10) about as long as the second joint; terminal joint more slender, and about two-thirds as long as the preceding; the whole limb devoid of hairs, except at the extremity, which bears five long, slender setæ. Mandible (fig. 11) divided at the apex into five sharp teeth, one of which is setiform; palp consisting of two very stout sub-quadrate joints, each of which is furnished with three setæ on its inner margin, the last also with four rather long apical setæ ("anterioribus 2 valde elongatis et curvatis," Sars); branchial lamina bearing only one short seta. Caudal laminæ (fig. 12) furnished with six ungues and with very small intercurrent marginal teeth; the ungues decrease only very slightly in length from behind forwards. Length ·70 mm.

Habitat.—Coasts of Norway, in depths of 120–250 fathoms, not common (G. O. Sars). Some specimens dredged in Loch Fyne are doubtfully referable to this species.

This species is known to us only from a single authentic specimen kindly sent to us by Professor G. O. Sars. Of this specimen we give a figure (fig. 9). In shell structure it seems to differ scarcely at all from *P. orbicularis*, but the details of the antennules, mandibles, and caudal laminæ are sufficiently distinct to

separate it decisively from that species. So far as the shell is concerned, it seems, compared with *P. orbicularis*, to be more evenly rounded when seen laterally, to be devoid of reticulation and light yellowish-green in colour.

3. **Polycope pustulata**, G. O. Sars.

1890. *Polycope pustulata*, . . Sars, G. O., "Oversigt af Norges Crustaceer, II. Branchiopoda, Ostracoda, Cirripedia" (Christiania Vidensk.-Selsk. Forhand.), p. 53 (separate copy).

Shell, seen from the side, sub-circular; anterior extremity scarcely produced; posterior subtruncate, its superior angle distinct, inferior obsolete; dorsal margin strongly arcuate, and almost angulated in the middle; ventral evenly convex. Seen from above, the outline is narrowed in front, very wide behind, and showing on each valve behind the middle a rounded pustuliform eminence. Valves smooth, scarcely reticulated, minutely denticulated on the ventral margin. Colour as in *P. orbicularis*. Length ·55 mm.

Habitat.—West coast of Norway, extremely rare.

This species we have never seen. Professor G. O. Sars, whose description is quoted above, has taken only one specimen, and it does not seem to have been noticed by any other naturalist.

4. **Polycope dentata**, G. S. Brady.

1866. *Polycope*(?) *dentata*, . . Brady, G. S., "Monograph of the Recent British Ostracoda," p. 472, pl. xxxv., figs. 58, 59.

1894. „ „ . . Müller, G. W., "Die Ostracoden des Golfes von Neapel." p. 233, pl. vii., figs. 16–23; pl. viii., fig. 25.

We have not ourselves met with any specimens of this species other than that on which the original description was based, but G. W. Müller has recently found it sparingly in the Mediterranean, and has figured both sexes in his work on the Ostracoda of that region.

Genus Polycopsis, G. W. Müller.

Shell, as in Polycope, but serrated on the anterior margin. Antennules five-jointed, first and second joints large, the last three joints small, anterior margin of the second joint forming two massive digitiform prolongations, each of which

ends in a stout seta. Larger branch of antenna eight-jointed. Mandible bent sharply downwards, very small and slender, very feebly toothed, all except the external tooth nearly obselete; palp large, the first joint bearing a small trisetose branchial lamina. Caudal laminæ bearing eight marginal ungues, the first two much smaller than the rest, which gradually increase in length backwards; between the ungues the margin is only slightly produced in an angular fashion; no setose tufts on the abdomen proper. In other respects the animal resembles Polycope.

1. **Polycopsis compressa** (Brady & Robertson).

(Pl. liv., figs. 11, 12; Pl. lxvii., figs. 4–8.)

1869. *Polycope compressa*, . . Brady & Robertson, "Ann. and Mag. Nat. Hist.," ser. iv., vol. iii., p. 20, pl. xxi., figs. 5–11.

1894. ,, ,, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel." p. 238, pl. vii., figs. 34–36, 38; pl. viii., fig. 21.

Shell (Pl. liv., figs. 11, 12), seen from the side, almost circular; dorsal and ventral margins very nearly equally arched; anterior margin dentated in a saw-like manner with about eighteen teeth, which gradually fade out at each end of the series (Pl. lxvii., fig. 7). Seen from above, the outline is compressed, ovate, greatest width situated in the middle and equal to somewhat less than half the length; anterior extremity moderately tapered, obtusely pointed; posterior broader and emarginate in the middle. Surface of the shell smooth, or finely punctate, and divided by a reticulated pattern into polygonal areas (Pl. lxvii., fig. 8).

Antennules (Pl. lxvii., fig. 4), especially the first two joints, very stout; the first joint bears only one marginal seta, second joint quite twice as long as the first, its outer margin produced into two long whip-like processes, which are very wide at the base (occupying nearly the whole length of the joint) and taper quickly to the points, each ending in a long lash; third joint very short and without setæ; fourth more than twice as long as the third, and having a seta on each margin near the apex; last joint very minute, and carrying five extremely long and slender terminal setæ.

Mandible (fig. 5) very small and bent on itself almost at a right angle (as in *Polycope*), its extremity divided into one sharp, well defined tooth, and a few much smaller and weaker processes; palp like that of *Polycope*, except that the laminar process of the first joint is trisetose. Ungues of the caudal laminæ

(fig. 6) tapered evenly without any bulbous dilatation at the base, fringed on their concave margins with exceedingly delicate cilia; margins of the laminæ produced between the ungues into small, sharp, triangular prominences; two similar, but sharper and more slender prominences are situated on the extremity beyond the last ungues. Length of the shell, ·6 mm.

Habitat.—On an oyster-bed in Clifden Bay, Ireland, 4–6 fathoms; dredged off the Eddystone lighthouse, and amongst the Scilly Islands, 10–40 fathoms (B. & R.); off St. Monan's, Firth of Forth (Mr. T. Scott); Messina, inside the harbour, 8 fathoms (Dr. Dohrn); off Capri, Naples, 4 fathoms (A. M. N.).

The very remarkable development of digitiform processes on the antennules is the character which most decidedly separates this genus from its near ally, *Polycope*, but the peculiar marginal denticulation of the shell, the trisetose mandible-palp, and the very slight development of the post-abdominal inter-unguial processes, are likewise of importance. We are indebted to the kindness of our friend Mr. Thomas Scott for the opportunity of examining and figuring freshly-taken specimens of this interesting species. We have thus been enabled to amplify and amend the original description which was drawn up from a scanty supply of dried specimens only.

PLATYCOPA.

Fam. **CYTHERELLIDÆ**.

Shell oblong, oblongo-ovate, or ovate, highly calcareous, and very hard. Seen from above, usually cuneate, or subcuneate; greatest breadth posterior. No rostrate process, or infero-anteal sinus. Valves unequal, the right the larger. Antennules seven-jointed, first two joints longer than the following, geniculated at their junction, following joints with numerous setæ, but no specialized sensory organ. Antennæ (Pl. LXVI., fig. 11) in form not unlike "the feet of *Copepoda*," flattened, consisting of two wide, sparingly setose basal joints, and two rami, one two-, the other three-jointed, joints flattened and densely setiferous. "Mandibulæ minimæ sed distinctæ, palpo magno pectinatim setoso instructæ. Membrorum sequentium tria modo adsunt paria minime pediformia, anteriora duo branchialia, posterius rudimentare" (G. O. Sars), but in the male the second and third maxillæ are much more largely developed, and suited for prehension. Copulative organs of the male elongated, cylindrical as in the *Conchœciadæ*. Posterior portion of the body consisting of many segments (at least ten in the female), and furnished dorsally with long setæ. Caudal laminæ small, fringed with setæ, which are small in front, but gradually increase in length backwards. Ova lodged within the shell of the female

Genus Cytherella, Bosquet.

Shell usually elongated and compressed, very thick and hard; valves very unequal, the right much the larger and overlapping the left through the whole circumference; surface very variable in sculpture, usually smooth or punctate, but sometimes rugose. Muscle spots (Pl. lxvi., fig. 9) numerous, forming an oval patch near the centre of the valves, spots elongated or linear, and arranged in two rows, the axes of the spots convergent, so as to form a pinnate pattern. Antennules very large and stout, geniculated at the junction of the first and second joints; first two joints massive, and bearing marginal tufts of setæ, the remaining joints gradually decreasing in breadth, and setose on the margins. Antennæ composed of a stout, bi-articulate basal portion and two branches; outer branch composed of two joints; inner longer and three-jointed; both branches furnished profusely with long, stout setæ.

"Mandibles very weak and strongly bent towards the apex; biting edge obliquely truncated, and furnished with a pectinate series of slender teeth" (G. O. Sars); palp two-jointed, large, cylindrical, and only slightly curved, beset along the greater part of its length with a series of extremely long, slender, closely-packed, and backward-curved setæ (40–50 in number), and bearing near the base a small branchial appendage. First pair of maxillæ composed of three setiferous biting lobes and a very large two-jointed palp, which is armed, like that of the mandible, with numerous long setæ; inner margin of the basal portion divided into three arcuate lobes, each of which bears four rather rigid and short backward-pointing setæ; the last joint of the palp ends in two setæ and a club-shaped sensory appendage; there is also a very large branchial lamina with numerous, very long, marginal setæ. Second pair of maxillæ very small, composed of an ovate lamina, which bears a few marginal tooth-like setæ, and a narrow ovate branchial plate, furnished with about twenty-two setæ, the last two setæ of different structure from the rest and non-plumose; in the male the limb is much more largely developed, and forms a powerful prehensile organ, the basal point of which is hatchet-shaped. Third pair of maxillæ, in the female, "rudimentary, and forming a simple setiferous lobe" (Sars), bearing an almost semicircular branchial plate with about fourteen setæ; in the male, prehensile, and not unlike the preceding pair. Caudal rami small, narrow, fringed with setæ, which gradually increase in length from the first on the ventral margin to the last, which is situated behind the middle of the dorsal margin, is stouter than the rest, strongly curved and directed forwards over the dorsum. Copulatory organs of the male very large, curved, subcylindrical. Abdomen divided into numerous segments, which are bordered more or less completely by narrow chitinous bands.

Professor G. O. Sars long ago described, though he did not figure, the remarkable resemblances which exist between some of the limbs of *Cytherella* and those of certain other *Entomostraca* belonging to the widely separated orders of *Branchiopoda* and *Copepoda*. The resemblance, for instance, is at once apparent between the extraordinary doubly branched antenna of *Cytherella* and the thoracic swimming-feet of many of the *Copepoda*. The appendages of the mandibles and first pair of maxillæ, on the other hand, with their profuse armature of immensely long, pectinately arranged setæ, are wonderfully like the feet of the *Sididæ*. Another interesting point which seems hitherto to have escaped notice is the division of the posterior part of the body into numerous distinct segments, so that the abdomen of the animal recalls in its general aspect the tail of a lobster, or perhaps of some *Branchiopoda* such as *Chirocephalus*. Except by G. O. Sars, no example of *Cytherella* have yet been observed in the living condition;* and in the European area, at any rate, it has never been taken except in considerable depths, nor in the tow-net either in the depths of the sea or at the surface. It may be assumed, therefore, though the profuse setose armature of the antenna would seem to adopt it for swimming, that it does not usually leave the bed of the sea to any great distance. Several recent species (about sixteen) have been described from various parts of the world, but except in the case of *C. abyssorum* and *C. serrulata*, the shell only has been seen. Numerous fossil species have also been recorded, but it is doubtful whether in some cases these species may not really belong to other genera.

1. **Cytherella serrulata**, n. sp.

(Pl. LXVI., figs. 3–6, 9–16; Pl. LXVII., figs. 15, 16.)

Shell of the female, seen from the side, subovate, almost reniform, a little higher in front than behind, greatest height equal to more than half the length; anterior extremity broadly and evenly rounded, sometimes slightly serrulated, but usually entire; posterior narrower, sloping rather steeply above, but broadly rounded below, and (in the adult female) fringed with a series of numerous minute teeth; dorsal margin straight, or very slightly arcuate, sloping gently downwards towards the posterior extremity; ventral distinctly sinuated in the middle. Seen from above, compressed, ovate, widest behind the middle, width equal to rather more than one-third of the length, subtruncate behind, with rounded angles, and tapering with a gentle curve towards the front, which is subacuminate. Surface of the valves smooth and polished, except the posterior extremity, which is roughened with numerous minute spines. Shell of the male much more compressed, and without marginal teeth. Seen from above, it is of almost equal width throughout, and quite thrice as long as broad; subtruncated

* This was written before the publication of G. W. Müller's monograph.

behind, and obtusely pointed in front. Length of male, 1·05 mm.; of the female, 1·08 mm.

Antennules (Pl. lxvi., fig. 10) seven-jointed, first two joints stout, and about equal in length, first joint bearing on its inner margin a single short spine-like seta, and four very slender, long setæ, towards the outer margin is attached an extremely long seta which reaches as far as the apex of the fifth joint; second joint having three very stout plumose setæ near the distal end of the inner margin, and a very small seta on the outer margin; third joint almost triangular, the inner margin being extremely short, a single long seta at the outer apex; the remaining joints are all furnished with non-plumose setæ on their inner edges, the fourth, fifth, and seventh joints have three, the sixth only two; the fourth and sixth joints bear also slender setæ on their outer margins. All the stronger setæ of this limb are contracted at the base (fig. 10 *a*) so as to move, apparently, as on a hinge at the point of insertion.

Basal portion of the antennæ (Pl. lxvi., fig. 11) very massive, first joint much longer than the second, quadrate, and having two rather long, simple setæ on its outer margin; second joint subtriangular, dilated distally so as to form a lobe at the inner side, to which are attached three long setæ; to the outer margin are attached four or five small spinules; first joint of the outer branch of the antennæ with four large setæ on the inner half of the distal extremity, from the outer half of which springs the second joint, which is much narrower than the preceding, is truncated at the apex, and bears seven terminal setæ, which increase in length progressively from the outer to the inner side; inner branch with the first joint as broad as long, widened distally, and furnished with about twelve distal setæ; second joint much narrower, rather longer than broad, with one seta on the innermost side of the distal extremity and two (?) on the outer side; last joint about equal in length to the preceding, but much narrower, with one seta on the inner margin and two long and very slender setæ at the apex.

Mandible (Pl. lxvi., fig. 12) small, obliquely truncated at the extremity, where it is divided into a few very small teeth, palp large, obscurely two-jointed, first joint very long, beset along its entire length with a closely packed series of very long curved setæ, and bearing at its distal end a small digitiform process which ends in a moderately long, straight seta; second joint about one-fourth as long as the first, somewhat plough-share shaped, and ending in a long seta; at the base of the limb is a very minute branchial plate with about six setæ. Biting portion of the first pair of maxillæ (Pl. lxvi., fig. 13) composed of three small setiferous lobes, palp indistinctly triarticulate: the large basal joint of the palp bears a series of long curved setæ similar to those of the mandible palp, and is divided into two arcuate marginal lobes, each of which bears four spine-like, but slender, setæ; second joint subquadrate, about half as long as the preceding, and on the inner margin four spine-like setæ similar to those of the first joint,

the distal outer angle produced and furnished with two setæ; last joint subconical, truncate at the apex, where it bears two simply curved setæ and a sensory filament with a club-shaped extremity; attached to the maxilla is also a very large, branchial lamina with numerous (Sars counts thirty-three) ciliated setæ. Second pair of maxillæ consisting, in the female (Pl. LXVI., fig. 15), of a small ovate membranaceous lobe, which bears on its inner margin six small spine-like setæ, and near the base a few irregularly disposed small hairs: to the base of the maxilla is also attached an ovate branchial plate fringed with twenty-two setæ, all of them very delicately plumose, except the last two, which are also denser and heavier in outline than the rest. In the male (Pl. LXVI., fig. 14), the maxilla and branchial plate resemble those of the female, but there is in addition a powerful prehensile three-jointed palp, the basal joint of which is very long and irregular in build, its inner margin presenting two angular bisetose prominences between which is a large and deep excavation; the opposite margin is strongly convex proximally, and irregularly sinuous on its distal half; second joint slender, not much over one-third as long as the preceding, somewhat angularly dilated at the base, and near the apex bearing two rather long setæ; third joint half as long as the second and rather more slender, terminating in a small, but stout unguis. Attached to the base of the limb on the outer side of the first joint is a small lamina which ends in two long setæ. Third pair of maxillæ (in the female not observed), in the male (Pl. LXVI., fig. 16), forming a strong prehensile four-jointed limb, first joint very slender and bearing two long setæ on a papilla in the middle of its outer margin, and a single seta on the inner margin near its junction with the second joint; second joint hatchet-shaped, about equal in length to the preceding, its inner side forming a large angular eminence, to the middle of which are attached two small setæ, and near the distal end two rather stout ungues, one much larger than the other; third and fourth joints much more slender and naked except for a minute seta near the extremity of the last, which ends in a small unguis. At the base of the limb is a semicircular branchial lamina which gives attachment to a series of about fourteen delicately plumose filaments, and has also near the origin of the filament a crescentic row of flask-shaped follicles (?), one opposite to the base of each filament. The abdomen in both sexes is divided into about ten segments, which have chitinous margins, and are produced downwards like the pleural plates of a lobster; the dorsal surface is setiferous. Attached to the side of the male abdomen (Pl. LXVII., fig. 16) on the segment in front of the copulatory organs is a pair of small foliaceous appendages which are fringed distally and on the outer margin with numerous very delicate setæ. The caudal laminæ form the last abdominal segment (telson). Each of the five preceding segments, in the female (Pl. LXVII., fig. 15), is furnished with a single dorsal seta, while the seventh, eighth, and ninth segments from the extremity have dorsal fascicles of three or four long setæ, as well as some minute spine-like setæ.

Caudal laminæ, in the female, truncate at the extremity, which bears five ungues; the stoutest is at the dorsal corner, has pectinated edges and is strongly and falcately curved, the second is small, the remaining three slender and each longer than the preceding; the lower, or front, margin of the lamina bears four peculiar setæ, flattened at the base, above which they are filiform, blunt-ended and pectinated. The hinder portion of the body in the male has each of the five segments preceding the caudal laminæ furnished only with a single dorsal seta, but is otherwise like that of the female. Copulatory organs of the male (Pl. lxvii., fig. 16) long, curvate, and cylindrical, resembling in form the same organs in *Conchœciadæ;* divided at the extremity into three small digitiform lobules.

Côte du Soudan, lat. 22° 49′ N., long. 19° 41′ W., 466–1168 fathoms, 12th–15th July, 1883; east of Canaries, 487 fathoms, 27th June, 1883; lat. 27° 31′ N., long. 16° 27′ W., July 7th, 1883; in lat. 25°, 217–528 fathoms, 9th July, 1883; off west coast of Morocco, latitude of El Arith, 600 fathoms; off Cap Blanc, 418–675 fathoms, and in other dredgings of which the precise localities are not indicated ("Talisman" Dredgings, M. le Marquis de Folin).

The figures and description of this species are taken entirely from specimens which have been kept in a dried condition for eleven or twelve years, some of which, however, after maceration in solution of potassium hydrate proved to be in good condition for dissection. We believe, therefore, that the foregoing will be found to be fairly accurate, though some of the more minute structures have escaped observation.

Amongst the numerous specimens of the shell which we have examined there is very considerable difference of contour, dependent, it may be, upon age and sex. The forms which we have figured are those which belong to the adult male and female.

2. **Cytherella abyssorum**, G. O. Sars.

(Pl. lxvi., figs. 1, 2, 15; Pl. lxvii., figs. 13, 14.)

1865.	*Cytherella abyssorum*,. . .	Sars, G. O.,	"Oversigt af Norges marine Ostracoder," p. 127.
1865.	,, *Beyrichi*, . . .	Brady,	"On New or Imperfectly Known Ostracoda" (Trans. Zool. Soc., vol. v.), p. 362, pl. lvii., fig. 3*a*, *b*.
1866.	,, *Scotica*, . . .	Brady,	"Brit. Assoc. Report," 1866, p. 211.
1866.	,, ,, . . .	Brady,	"Monog. Recent Brit. Ostrac.," p. 473, pl. xxxiv., figs. 18–21.

Shell of the female, seen laterally, subelliptical, of equal height throughout, height equal to considerably more than half the length, extremities equal and broadly rounded; superior margin almost straight, inferior very slightly sinuated

in the middle. Seen from above, the outline is subcuneate, widest behind, the greatest width being equal to half the length; the lateral margins diverge gently and in as lightly sinuated line from the front backwards; the anterior extremity is wide, subtruncate, or very obtusely rounded, the posterior subtruncate, with well rounded angles, and about twice as wide as the anterior. The surface of the valves is covered with rather large circular impressed puncta, and there is generally a more or less distinct transverse central depression. In the fresh condition the shell is furnished at the extremities with a few rigid hairs, those of the anterior margin being extremely long, but not visible in dried specimens. Colour, tawny-white or yellowish. The shell of the male does not differ much except in being more compressed when seen dorsally. Length of female, ·95 mm.; of male, ·90 mm. (G. O. Sars).

The soft parts of the animal do not differ materially from those of *C. serrulata*, but the second and third maxillæ are here figured.

Generally distributed round the coasts of Norway in depths of 100–300 fathoms (G. O. Sars and A. M. N.); Nice (Marquis de Folin). Taken also during the cruise of the "Valorous" in 410 fathoms (Station 6).

3. **Cytherella lævis**, Brady.

(Pl. LXVI., figs. 7, 8.)

1866. *Cytherella lævis*, . . Brady, "Brit. Assoc. Report," 1866, p. 211.
1866. ,, ,, . . Brady, "Monog. Recent Brit. Ostracoda," p. 474, pl. xxxiv., figs. 15–17.

Shell of the female, seen from the side, subelliptical, scarcely higher in front than behind, greatest height in the middle, and equal to two-thirds of the length, extremities well rounded, the posterior rather the narrower of the two; dorsal margin rather boldly and evenly arched, ventral nearly straight. Seen from above, the outline is subovate, twice as long as broad, the greatest width situated a little behind the middle; the anterior extremity is rather obtuse, the lateral margins diverging with a gentle curve to the posterior extremity, which is wide and truncated. Surface of the valves quite smooth, bearing a few short scattered hairs, the left valve narrow and almost straight dorsally, while the left is very strongly arched. Colour whitish. Length of female 1·05 mm.; of male 0·9 mm. The shell of the male is smaller, and the valves are flatter, so that when seen dorsally the lateral margins are less distinctly curvate.

Dredged on the west coast of Scotland (Mr. Jeffreys); west coast of Morocco, off Cape Cantin, 418 fathoms; off the coast of the Soudan, 400-460 fathoms ("Talisman" dredgings), and in a dredging of the "Travailleur" (1880), of which the precise locality is not indicated (Marquis de Folin).

APPENDIX.

In this Appendix we notice the *Ostracoda* which have recently been described, together with new genera and species which have been or are here characterized; we give also a record of additional habitats in the case of some of the rarer species where the geographical range has by such habitats been extended.

Genus Cyclocypris, Brady & Norman, 1889.

(Brady & Norman, Pt. I., p. 70.)

Shell more or less ovate, and excessively tumid; valves may be punctate and slightly hispid, but are always polished and glossy. Antennæ five-jointed in female, six-jointed in male, having ungues of great length, and the setæ of third joint, about five in number, excessively long and reaching very far beyond the ungues. Mandible palp with last joint not slender, nor more than twice as long as broad. Lobes of the first maxillæ short, not so long as the first joint of the palp. Second feet having at the termination one small curved seta, a second seta of moderate length and a third very long, equalling almost the whole limb, upon which it is reflexed. Caudal rami of moderate length, strongly built, ending in two strong ungues, which are much curved at the apex and have a minute seta in front of them; the seta of the dorsal margin is situated far back, only a little beyond the middle of the limb. Males common.

1. **Cyclocypris globosa** (G. O. Sars).

(Brady & Norman, Pt. I., p. 71; Pl. XI., figs. 10–18; Pl. XIV., figs. 1, 2.)

2. **Cyclocypris serena** (Koch).

1889. *Cypria serena*, ... Brady & Norman, p. 70.
1890. *Cyclocypris serena*, . . Sars, G. O., "Oversigt af Norges Crustaceer: II. Branchiopoda, Ostracoda, Cirripedia," p. 55.

3. **Cyclocypris lævis** (O. F. Müller).

1889. *Cypria lævis*, ... Brady & Norman, p. 69.
1890. *Cyclocypris lævis*, . . . Sars, G. O., *loc. cit.*, p. 55.
1891. „ „ . . . Vávra, "Monographié der Ostracoden Böhmens," p. 68.

Professor G. O. Sars was certainly quite right in removing the two preceding species into the genus *Cyclocypris*. Our figures, Pt. I., Pl. XI., figs. 15, 16, were not correct as regards the setæ of the limbs drawn, of which we now give correct descriptions in the characters of the genus.

Of what we called in Part I. *Cypria Joanna* (Baird), we know nothing, and therefore do not assign it to this genus; the doing so would very probably be only giving another synonym.

Genus Cypria, Zenker, 1854.

Shell subovate or reniform, subcompressed; valves punctate or striated. Antennæ five-jointed in female, six-jointed in male, ungues very long, the setæ of the third joint, about five in number, excessively long, reaching very far beyond the ungues. Mandible-palp with the last joint very long and slender, 4–5 times as long as broad. Lobes of first maxillæ very short, not nearly so long as the first joint of the palp. Second foot ending in two small setæ of equal length, and a third very long, which is reflexed upon the limb. Caudal rami of moderate length, strongly built, ending in two moderately robust ungues, only slightly bent at the apex, terminal seta minute, dorsal seta situated far back, only a little beyond the middle of the ramus. Males common.

1. **Cypria exsculpta** (Fischer).
2. **Cypria opthalmica** (Jurine).
3. **Cypria lacustris**, Lilljeborg MS.

Pl. LXVIII., figs. 3, 4.

1890. *Cypria lacustris*, . . Sars, G. O., *loc. cit.*, p. 54.

Charact. Specif.—*C. ophthalmicæ* valde affinis, sed distinguenda testâ adhuc magis compressâ et paulo humilione limbo antice et postice latiore et valde hyalino. Animal sat pellucidum colore pallide flavescente maculis testæ minus distinctis et sæpius omnino deficientibus. Longit. testæ feminæ ·80 mm.

Habitat in lacubus majoribus in profunditate 6–30 orgyarum. Sweden (Lilljeborg); Norway (G. O. Sars).

Professor Lilljeborg has kindly sent one of us (A. M. N.) specimens of this form. We can add nothing to Sars' description quoted above. The form certainly comes exceedingly near to that of *C. ophthalmica*. Whether it is to be regarded as a species or a variety is an open question. Some variation must be allowed in species, and there is certainly considerable variation in many *Ostracoda*, for example, in such common forms as *Cypris fuscata*, *virens*, and *incongruens*.

Genus Scottia, Brady & Norman.

Scottia Browniana (T. R. Jones).

The habitat on the shores of Loch Fadd, in the Isle of Bute, where this species was found by Mr. T. Scott, is so remarkable, that it is worthy of further notice. It was visited by A. M. N. in company with Mr. D. Robertson, who knew the spot. A spring rises on a bank close to the loch, into which the water finds its way among the grass; the water is nowhere trickling more than two or three inches deep among the herbage. Here, amidst multitudes of *Difflugiæ*, *Scottia Browniana* lives, with *Ilyodromus Robertsoni*, *Herpetocypris reptans* and *tumefacta*, *Cypridopsis Newtoni*, *Candona candida*, and *Candonopsis Kingsleii* as its companions.

Genus Cypris.

Until quite lately males in this genus were unknown; and up to the present time no male has been found in the British islands.

In 1889 Professor G. O. Sars, in his Paper "On some Freshwater Ostracoda and Copepoda raised from dried Australian Mud" (Christ. Videns-Selks. Forhand.), described more fully the genus *Cyprinotus*, Brady, to which he assigned the British forms *Cypris salina*, Brady, and *Cypris fretensis*, Brady, and gave as one of the leading characters the fact that he had raised males of *Cyprinotus dentato-marginatus*, Baird, from the Australian mud. "Moreover," he wrote, "there is a feature that would seem to separate this genus," i.e. *Cyprinotus*, "very markedly from the genus *Cypris* (sens. strict.), and to bring it in closer relationship with the genus *Cyprois* of Zenker; as with the latter genus the propagation is sexual, and not as in the true genus *Cypris* exclusively parthenogetical, the males being almost as frequent as the females."

It is true that Dr. S. Fischer, as long ago as 1855 (*Beitrag zur Kenntniss der Ostracoden*), had recorded males in his *Cypris prasina*, *Cypris exserta*, *Cypris rivularis*, and *Cypris mareotica*, but the first would seem to be referable to Sars' genus *Cyprinotus*, the second is perhaps a *Candona*, the third also probably a *Candona*, the last doubtful, until now identified by Moniez as a true *Cypris*. More recently Professor C. L. Herrick ("Freshwater and Marine Crustacea of Alabama," Mem. Denison, Sci. Assoc., vol. i., 1887), states that he had found in Alabama males of a *Cypris* which he refers to *C. virens*, and of a species described by him as *C. modesta*. It remained, however, for M. R. Moniez finally to clear up all doubt on this matter. In two Papers published in 1891,* he records the occurrence of

* "Les Mâles chez les Ostracodes d'eau douce" (Revue Biol. du Nord. de la France), and "Faune des Lacs salés d'Algierie" (Mem. de la Soc. Zool. de France).

males in *Cypris virens*, Jurine; *C. incongruens*, Ramdohr; *C. mareotica*, Fischer; *C. ungulata*, Moniez; *C. balnearica*, Moniez; also in the genus *Herpetocypris*, as exemplified in *H. spinosa*, Moniez,* an Asiatic species; and in the genus *Cypridopsis*, as evidenced in *C. villosa*, Jurine.

In the same year Vávra, in his work on the Ostracoda of Bohemia, described and figured the male of *C. incongruens.*

Among Hungarian Ostracoda recently sent to us for examination by Dr. Daday, we found *C. incongruens* to be the prevailing species, and in many of the gatherings both sexes were present.

Males of *Cypris* have thus been found in the south and east, but as far as we know the curious fact remains that no representatives of that sex have been observed in northern or western Europe north of Spain.

Cypris incongruens, Ramdohr.

(Pl. LXIV., figs. 17, 18; Pl. LXVIII., figs. 22, 23.)

We figure the shell, second maxilla, and ejaculatory duct of the male of this species from a Hungarian specimen received from Dr. Daday.

Genus CYPRINOTUS, G. S. Brady, 1886.†

This genus was established by shell characters to receive an Ostracod from Ceylon. Professor Sars has raised the same species, as well as the earlier described *Cypris dentato-marginata* of Baird, from Australian mud. Of this last species he has reared the males, and drawn up the following generic character:—

"Shell rather thin, compressed, oval or subtriangular, height considerably exceeding the half length; dorsal margin greatly vaulted; ventral margin almost straight. Valves rather unequal, the right being overlapped by the left both anteriorly and posteriorly, but sometimes dorsally produced far above the level of the latter. Free edges of the left valve smooth, and having at either extremity a rather broad hyaline border, those of the right armed with a regular series of small tuberculiform teeth. Inner duplicatures of both valves rather narrow. Natatory setæ of lower antennæ very elongate, reaching far beyond the terminal claws. Palpus of first pair of maxillæ rather narrow, last joint linear; masticatory lobes of middle length. Caudal rami narrow, claws smooth, seta of dorsal edge close to the claws. Propagation sexual. Prehensile palps of second pair of maxillæ in male rather powerful, unequal. Copulative organs compara-

* Perhaps, however, this may prove not to be a true *Herpetocypris.*

† "Entomostraca collected by Mr. A. Haly in Ceylon."—Linn. Soc. Journal—Zoology, vol. xix., p. 301.

tively small, with outer plate obtuse, linguiform. Ejaculatory tubes narrow, with numerous wreaths of spines, crown simple, not produced."

To the genus *Cyprinotus*, thus defined, is probably referable the following :—

Cyprinotus prasinus (S. Fischer).

(= **Cypris salina**, Brady & Norman, Pt. I., p. 78).

Genus Stenocypris, G. O. Sars, 1889.

"Shell very narrow and elongate, height by far not attaining half the length, ventral margin distinctly sinuated in front of the middle. Valves subequal, free edges smooth, inner duplicatures very large, especially at the anterior part. Natatory setæ of antennæ not reaching beyond the terminal claws. Palpus of first pair of maxillæ very narrow, cylindrical, last joint small, masticatory lobes long and narrow. Caudal rami rather large, more or less lamelliform, dorsal edges sometimes pectinate, claws very unequal, both coarsely denticulated, seta of dorsal edge absent, or very small, the apical one rather elongate. Propagation exclusively parthenogenetical."

Such is Sars' description of a genus described in his Paper "On some Freshwater Ostracoda and Copepoda raised from dried Australian mud" (Christ. Vidensk-Selsk. Forhand. 1889). To this genus is referable the following European species :—

Stenocypris fasciata (O. F. Müller).

Herpetocypris fasciata, . . Brady & Norman, 1st Part, p. 86, pl. ix., figs. 13, 14; pl. xii., fig. 1.

Stenocypris ,, . . Sars, G. O., "Oversigt af Norges Crustaceer: II. Branchiopoda, Ostracoda, Cirripedia," Christ. Vidensk Selsk. Forhand., 1890, pp. 17 & 58. Separate copy.

Genus Herpetocypris, Brady & Norman.*

Herpetocypris glacialis, G. O. Sars.

(Pl. lxviii., figs. 1, 2.)

1886. *Cypris Jurinii*, ... Sars, G. O., "Den Norske Nord. Exped. Crustacea," Pt. ii., p. 75 (nec Zaddach).

1890. *Herpetocypris glacialis*, . . Sars, G. O., "Oversigt af Norges Crustaceer: II. Christ. Vidensk-Selsk. Forhand.," 1890, p. 61.

* In Part I., for *Erpetocypris* read *passim Herpetocypris*.

"Testa feminæ sat ventricosa, a latere visa oblongo-ovata, vix duplo longior quam altior, altitudine maxima paulo ante medium sita, extremitate antica rotundata, postice obtusa, margine dorsali æqualiter arcuato, angulum tamen obscurum supra oculum formante, ventrali medio perparum sinuato; supra visa late fusiformis, latitudine maxima fere altitudinem æquante paulo pone medium sita, extremitate utraque acuminata. Valvulæ subequales, sat tenues, nitidæ, pilis dense obsitæ. Color obscure fuscatus, supine macula magna viridi irregulari, utrinque in fascias duas angustas diagonales retro vergentes exserta. Setæ natatoriæ antennarum superiorum sat elongatæ, eædem inferiorum vero brevissimæ et rudimentares. Ungues apicales antennarum inferiorum et pedum primi paris subtiliter denticulati. Rami caudales mediocres apicem versus attenuati, unguibus dimidiam rami longitudinem superantibus, seta marginis dorsalis tenui unguibus approximata. Longit. testæ, 1·60 mm."

Distribution.—Vardo, in East Finmark, and in marshes at Advent Bay, Spitzbergen (G. O. Sars).

Our figures are taken from types received from Professor G. O. Sars.

Genus Ilyodromus, G. O. Sars.

"Contrib. Knowledge of Freshwater Entomostraca of New Zealand" (Videns-Selks. Skrifter, 1894), p. 38. Separate copy.

"Shell highly compressed and, seen laterally, oblong in form, with the dorsal edge straight in the middle, the ventral more or less sinuated. Valves generally not very unequal, the left one being in every case the larger, inner duplication very broad and shelf-like. Surface of shell in most of the species striated longitudinally. Setæ of the superior antennæ shorter than in *Candonocypris*, those of the inferior ones poorly developed, not reaching beyond the terminal claws. First pair of maxillæ of nearly the same structure as in the genus *Candonocypris*. Caudal rami, on the other hand, much coarser, and armed with three strong claws, increasing in length distally. Animal quite devoid of swimming power. Propagation exclusively parthenogetical."

In this genus the caudal rami have "three instead of only two claws, the dorsal seta being here replaced with a claw of the same appearance as the other two."

To this description of Sars we may add that the chief teeth of the external member of the first maxillæ are strongly dentated on the edges, as in the genera *Cypris* and *Herpetocypris*.

One of the following species Sars has himself referred to this genus; but to admit all the description of the dorsal margin of the shell will require modification.

1. **Ilyodromus olivaceus**, Brady & Norman.

1889. *Herpetocypris olivacea*, . . Brady & Norman, "Mon. Ostracoda-Podocopa," Pt. i., p. 89, pl. i., figs. 3, 4.

1891. *Cypris* ,, . . Vávra, "Mon. der Ostracoden Böhmens.," p. 88, fig. 29.

1894. *Herpetocypris* ,, . . Croneberg, "Beitrag sur Ostracoden Fauna der Umgegend von Moskau" (Bull de Moscou), p. 14, pl. vii., fig. 13 *a–d*. Separate copy.

1895. *Ilyodromus olivaceus*, . . Sars, G. O., "Contrib. Freshwater Entom. of New Zealand" (Vidensk-Selks. Skrifter, 1894), p. 39. Separate copy.

Distribution.—Bohemia (Vávra); near Moscow (Croneberg).

2. **Ilyodromus Robertsoni**, Brady & Norman.

1889. *Herpetocypris Robertsoni*, . . Brady & Norman, "Mon. Marine and Freshwater Ostracoda-Podocopa," pt. i., p. 88, and woodcut.

Distribution.—Norway (G. O. Sars).

Genus Prionocypris,* n. g.

Shell subtriangularly oblong, higher in front than behind, compressed; surface punctate and hirsute; the extremities more or less denticulately serrated. Antennæ with short setæ; animal incapable of swimming freely. Maxillæ having the claws of the outer member quite simple; palp with last joint slightly widening at the extremity, its length slightly exceeding the breadth. Caudal rami slender, the dorsal margin quite smooth; dorsal seta very near the terminal claws.

The shell in this genus is markedly distinct from that of *Herpetocypris reptans* and its allies. The caudal rami are smooth-edged, and not denticulated; but a very marked character consists in the simple claws of the outer member of the first maxillæ. These in *Cypris* and in *H. reptans* have their edges denticulated (see figures of these claws represented in many species figured by Vávra).

* πρίων, a saw. Named from the serrated extremities of the valves.

Prionocypris serrata (Norman).

1889. *Herpetocypris serrata*, . . Brady & Norman, "Mon. Podocopa," p. 87.

Genus Cypridopsis, G. S. Brady, 1867.

Cypridopsis, as described by Brady ("Intellectual Observer," 1867, p. 117), was founded on the character of the caudal rami being "quite rudimentary, consisting of two slender, setiform processes, springing from a common base." Three species were included in it, *C. vidua*, *aculeata*, and *villosa*. The generic characters do not apply to the first, which must be removed from the genus.

The species described which should be retained in the genus are :—

1. **Cypridopsis aculeata** (O. G. Costa).

G. O. Sars thinks that the *Cypris aculeata* of Lilljeborg is the same species as that which was described many years before by O. G. Costa under the same name (*Fauna del Regno di Napoli Crostacei Cypris*, p. 11, Pl. III., fig. 5). It may be so, for Costa's description and figure agree closely with the northern form.

2. **Cypridopsis villosa** (Jurine).
3. **Cypridopsis Newtoni**, Brady & Robertson.
4. **Cypridopsis variegata**, Brady & Norman.

Genus Pionocypris,* nov. nom.

= **Cypridopsis**, G. O. Sars, 1889 (*nec* Brady).

Sars' characters of the genus are as follows :—

Shell very tumid, more or less globular in form ; dorsal margin boldly arched, ventral nearly straight. Valves subequal, rather thin, hairy, inner duplicatures narrow. Eye usually broad, transverse. Upper antennæ (= antennules) comparatively short, but having very long natatory setæ ; lower antennæ rather powerful, with greatly elongated apical claws, and the natatory setæ reaching beyond their tips. Labrum very large and vaulted. First pair of maxillæ with palps and masticatory lobes narrow and elongate ; second pair without any branchial lamella. Legs about as in *Cypris*. Caudal rami extremely small and narrow, but of quite normal structure, claws slender and setiform, three on each ramus, besides a very small apical bristle. Propagation exclusively parthenogenetical.

* πίων, fat, plump.

1. **Pionocypris vidua** (Müller), Pl. lxiv., fig. 19.

= **Cypridopsis vidua**, Brady & Norman.

The caudal rami in this species differ from the figure given by Sars of the same organs in the Australian *Cypridopsis globulus*, G. O. Sars, and the definition of the genus requires slight modification to embrace them. Seen in situ from below, they exactly resemble the same organs in Cypridopsis (as limited above), that is, all that can be seen are apparently narrowly triangular rami ending in a single, very long seta. But when a lateral view is obtained (and in consequence of their extremely small size and their position it is not very easy to dissect the rami out and obtain this view), the ramus is seen to be unusually deep in proportion to its length, and to end in two very long subequal setæ, slightly behind which the dorsal margin bears a minute seta. We have not been able to detect any third minute apical seta, but it is possible that there may be one.

2. **Pionocypris obesa** (Brady & Robertson).

1869.	*Cypridopsis obesa*,	.	.	Brady & Robertson, "Notes on a Week's Dredging in the West of Ireland," Ann. & Mag. Nat. Hist., ser. 4, vol. iii., p. 12, pl. xviii., figs. 5–7. Separate copy.
1870.	,,	,,	. .	*iidem ibidem*, ser. 4, vol. vi., p. 15.*
1874.	,,	,,	. .	Brady, Crosskey, & Robertson, "Post-Tert. Entom.," p. 128, pl. i., figs. 1–4.
1889.	,,	*vidua*,	. .	(Variety). Brady & Norman, "Mon. Ostrac. Pt. i., Podocopa," p. 89.
1890.	,,	*obesa*,	. .	Sars, G. O., "Oversigt af Norges Crustaceer: ii. Branchiopoda, Ostracoda, Cirripedia" (Christ. Vidensk-Selsk. Forhand.), p. 92.

Sars has restored this form to specific rank. We have expressed our conviction that it is only a variety of *P. vidua*, and have nothing to add to what may be said on either side of the question, but give a list of the localities in which the form *obesa* has been found.

Habitat.—Mullingar Canal, Dublin; Whittlesea Mere; Rivers Nene and Cam;

* In this Paper Brady and Robertson give reasons which seemed to them to make it doubtful whether this form should be regarded as distinct, or as a variety of *C. vidua*.

Norfolk Broads (Brady & Robertson). River Ouse, near Lynn, Norfolk; Fulwell Cemetery, near Sunderland (G. S. Brady).

Distribution.—Rivers Maas and Scheldt in Holland (G. S. Brady). Norway (G. O. Sars).

Fossil.—Fluviatile clays, Hornsea, Yorkshire, and Branston Fen.

3. **Pionocypris picta** (Straus).

Genus Cyprois, Zenker.

Cyprois marginata (Straus).

1821. *Cypris marginata*, . . . Straus, H. E., "Mémoire sur les Cypris Mém. du Mus.," vol. vii., p. 59, pl. i., figs. 20–22.

1889. *Cyprois flava*, ... Brady & Norman, "Monograph Ostracoda," i., p. 97, pl. viii., figs. 18, 19; pl. xii., figs. 13–21, 38.

1890. ,, *marginata*, . . Sars, G. O., "Oversigt af Norges Crustaceer," ii., p. 54.

We think that Professor Sars has rightly referred this to the hitherto unidentified *C. marginata* of Straus.

Genus Ilyocypris, Brady & Norman.

Professor G. O. Sars is perhaps right in regarding two species as having been confounded by authors under the name *Cypris gibba*, Ramdohr. The differences in the two forms had long been a matter of perplexity to us.

1. **Ilyocypris gibba** (Ramdohr).

(Pl. lxviii., figs. 20, 21.)

1868. *Cypris gibba*, . . . Brady, "Mon. Brit. Ostrac.," *partim*, pl. xxiv., fig. 54; pl. xxxvi., fig. 2.

1889. *Ilyocypris gibba*, . . Brady & Norman, "Monog. Marine & Freshwater Ostracoda," p. 107 *partim*, pl. xxii., figs. 1–5.

1890. ,, ,, . . Sars, G. O., "Oversigt af Norges Crustaceer: ii. Branch. Ostrac. Cirrip.," p. 58.

1891. ,, ,, . . Vávra, "Monog. der Ostracoden Böhmens," p. 57, fig. 17.

1894. ,, ,, . . Var. *tuberculata*. Kertesz, K., "Daten zur Ostracoden-Fauna der Umgegand Szeghalom's. Természetrajzi Füzetek," 1893 (1894), p. 169, pl. vi., figs. 1–12.

In this form the shell is not only transversely bisulcated, but also tuberculated (see Brady, 1868, fig, 24. Kertesz, figs. 1, 2 represent a more than commonly tuberculated form), and the antennæ have the antepenultimate joint furnished with a long brush of setæ which extend beyond the terminal claws (see Brady, 1868, Pl. xxxvi., figs. 2, 6, and Brady & Norman, Pl. xxii., fig. 1).

It is the form figured by T. R. Jones in "Tertiary Entom.," 1856, Pl. i., fig. 3 *a*, as *Cypris gibba*; by Fischer, "Das Genus Cypris," Pl. v., figs. 5–8, as *Cypris biplicata;* and by Brady, Crosskey, and Robertson, "Mon. Post-Tertiary Entomostraca," as *C. gibba*, Pl. xv., figs. 5, 6.

2. **Ilyocypris Bradii**, G. O. Sars.

(Pl. lxiii., figs. 22, 23; Pl. lxviii., figs. 18, 19.)

1868. *Cypris gibba*, . . . Brady, "Mon. Brit. Ostrac." *partim*, pl. xxvi., figs. 47–50.

1890. *Ilyocypris Bradii*, . . Sars, G. O., "Oversigt af Norges Crustaceer: ii. Branch. Ostrac. Cirrip.," p. 50.

1891. „ *gibba*, . . Var. *repens*. Vávra, "Monog. der Ostracoden Böhmens," p. 60, fig. 18.

Ilyocypris Bradii is distinguished from *I. gibba* by the characters—1st, that the shell, though similarly bisulcated transversely, is not tuberculated; and 2nd, that the setæ of the antepenultimate joint of the antennæ are very short, and scarcely reach the bases of the terminal spines (Pl. lxiii., fig. 22).

The following synonyms appear to be referable to this form rather than to the last:—*Monoculus puber*, Jurine (?), and *M. bistrigatus*, Jurine (junior?); *Cypris biplicata*, Koch; *C. bistrigata*, Zaddach; *C. sinuata*, Fischer; and *C. bistrigata*, Lilljeborg. It appears to us to be unquestionably *C. biplicata*, Koch; and that name it will probably have to bear, if not one of Jurine's names.

Genus Candona.

Professor G. O. Sars has described several forms very closely allied to *C. pubescens*, which he considers distinct. To his usual great kindness we are indebted for specimens of these Candonæ, and we here quote his descriptions, and add illustrations from his specimens.

Candona compressa, Koch.

= **Candona pubescens**, Brady & Norman.

Sars would retain Koch's two species, and attribute the name *C. compressa* to

the British form hitherto described by us. Of *C. pubescens*, Koch (G. O. Sars), he gives the following characters:—

Candona pubescens, Koch.

(Pl. LXIII., fig. 24; Pl. LXIV., figs. 20, 21; Pl. LXVIII., figs. 7–9.)

1837. *Cypris pubescens*, . . Koch, C. L., "Deutschlands Crustaceen Myriapoden und Arachniden," H. XI., No. 6.

1890. *Candona* ,, . . Sars, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," Videnskab-Selsk. Forhand., p. 64.

"Testa feminæ a latere visa ovato-subreniformis, altitudine maxima dimidia longitudine multo majore in parte postica sita, extremitate antice anguste rotundata, postica sat expansa adque angulum inferiorem obtusa; margine dorsali postice valde arcuato antice declivi, ventrali leviter sinuato; supra visa oblonga, latitudine maxima altitudine multo minore in medio sita, extremitate antica angustiore. Testa maris eadem feminæ paulo major et postice magis expansa, margine ventrali distinctius sinuato. Valvulæ parum inæquales, pilis longissimis ubique hispidæ, albæ, opacæ, parum nitidæ, tuberculis nullis visibilibus. Rami caudales breves, vix flexuosi, apicem versus sensim attenuati, unguibus subæqualibus dimidio ramo multo longioribus, margine altero subtiliter denticulato, seta marginis dorsalis haud elongata ad partem ultimam tertiam rami sita. Longitudo testæ maris 1·30 mm."

Habitat.—Pond in Wanstead Park, Essex, and at Pavenham, Bedfordshire (Mr. Scourfield).

Distribution.—In marshes in the neighbourhood of Christiania (G. O. Sars).

For specimens from the English localities we are indebted to the kindness of Mr. Scourfield. Figures from these specimens are given in Plate LXVIII. The second maxilla and caudal ramus are shown in Plates LXIV. and LXIII.

Candona stagnalis, G. O. Sars.

(Pl. LXVIII., figs. 14–17.)

1890. *Candona stagnalis*, . . Sars, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," Christ. Videns-Selsk. Forhand, p. 69.

1891. ,, *ambigua*, . . Scott, T., "Invertebrate Fauna of Inland Waters of Scotland," Ninth Report Fishery Board for Scotland, p. 277, pl. iv., figs. 7 *a–c*, ♂.

Having received through the kindness of the describers type specimens of the

above two named *Candonæ*, we find them to be, unquestionably, the same species, which is nearly allied to *C. Zenkeri*. We give Sars' description in his own words, so as to do full justice to his views with respect to the several very closely allied forms which he regards as distinct:—

"Testa feminæ a latere visa oblongo-subreniformis, fere duplo longior quam altior, extremitate antica rotundata, postica quam in *C. compressa* minus expansa, supine vix angulata, inferne obtusa, margine dorsali subrecto et parum modo declivi, ventrali leviter sinuato; supra visa oblongo-ovata, latitudine maxima altitudine paulo minore pone medium sita, antice quam postice magis attenuata. Testa maris ab eadem feminæ parum discrepans, extremitate postica paulo magis expansa et ad angulum inferiorum mutica. Valvulæ parum inæquales, læves, nitidæ, subpellucidæ, sparse pilosæ. Rami caudales fere recti et sensim attenuati, unguibus sat fortibus et margine altero conspicue dentatis, seta marginis dorsalis haud magna, ad partem ultimam tertiam rami affixa. Longitudo testæ, 0·90 mm."

Habitat.—Lochgelly Loch, Fifeshire (Thomas Scott).

Distribution.—In ditches and marshes round Christiania (G. O. Sars).

Candona Zenckeri, G. O. Sars.

(Pl. lxiii., fig. 25; Pl. lxviii., figs. 12, 13.)

1890. *Candona Zenckeri*, . . Sars, G. O., "Oversigt af Norges Crustaceer: ii. Branch. Ostrac. Cirrip." Vidensk-Selsk. Forhand, p. 66.

"Testa feminæ sat compressa, a latere visa oblonga-reniformis, duplo circiter longior quam altior, extremitate antice obtuse rotundata, postica sat expansa adque angulum inferiorem arcuata et limbo tenui hyalino circumdata, margine dorsali medio recto et paulo declivi, angulo distincto et antice et postice terminato, ventrali profundius sinuato; supra visa anguste oblonga, latitudine maxima altitudine multo minore fere mediana, antice quam postice magis attenuata. Testa maris ut vulgo in parte postice expansa, angulo superiore sat prominente. Valvulæ sparse et breviter pilosæ, semipellucidæ, lævis, nitidæ, margaritaceæ, dextra sinistra nonnihil majore. Rami caudales subrecti, attenuati, unguibus dimidiam rami longitudinem vix superantibus, sublævibus, seta marginis dorsalis brevi ad partem ultimam quartam rami affixa. Longitudo testæ, 0·88 mm."

Habitat.—It is a British species, having been found thirty years ago by A. M. N. in a pond at Ferry Hill, in the county of Durham, remaining since in his collection as a doubtful form.

Distribution.—Rare in marshes round Christiania (G. O. Sars).

Candona Kingsleii, Brady & Robertson.

Vávra (*loc. cit.* p. 54) has established a genus *Candonopsis* to receive this species. He has only seen the male, but from it draws the following generic characters:—

Antennæ six-jointed, with two peculiar sense organs between the fourth and fifth joints. Mandible palp very long. Second maxillæ with a trisetose branchial plate. Caudal rami slender; seta of the dorsal margin absent.

Distribution.—Bohemia (Vávra); Norway (Sars).

Candona rostrata, Brady & Norman.

Distribution.—Neighbourhood of Moscow (Croneberg); Norway (G. O. Sars).

Besides the species referred to in the preceding notes, Professor G. O. Sars has, in his "Oversigt," added the following to the species previously known as included in the fauna of Norway:—

Cypria exsculpta (Fischer).
Cypris elliptica, Baird.
,, *reticulata*, Zaddach = *affinis*, [Fischer.
,, *obliqua*, Brady.
,, *crassa*, O. F. Müller.
Herpetocypris Jurinii (Zaddach).
,, *tumefacta* (B. & R.).
Cypridopsis aculeata, Brady = *Potamocypris aculeata*, Sars.
Candona fabæformis (Fischer).
,, *hyalina*, B. & R.
,, *acuminata* (Fischer).

Genus Bythocypris, G. S. Brady.

Professor Sars removes *Bairdia obtusata*, G. O. Sars, and *B. complanata*, Brady, into this genus.

Argillœcia cylindrica, G. O. Sars.

Distribution.—East Finmark, at Vadsö, in 10 fathoms, and Klosterelv Fiord, tidemarks (A. M. N.).

Cythere confusa, Brady & Norman.

Distribution.—Vadsö, East Finmark (A. M. N.).

Cythere pellucida, Baird.

Distribution.—East Finmark (A. M. N.).

Cythere gibbosa, Brady & Robertson.

Distribution.—Klosterelv Fiord, East Finmark, tidemarks (A. M. N.).

Cythere limicola, Norman.

Distribution.—Fiords of East Finmark, in 5–30 fathoms (A. M. N.).

Cythere cluthæ, B. C. & R.

Distribution.—Living in 125–150 fathoms, Varanger Fiord, and 20–30 fathoms, Bog Fiord, East Finmark (A. M. N.).

Cythere villosa (G. O. Sars).

Distribution.—East Finmark (A. M. N.).

Cythere(?) semiovata, T. Scott.

(Pl. lxiii., figs. 14, 15.)

1890. *Cythere*(?) *semiovata*, . . Scott, T., "Addit. Fauna, Firth of Forth," Eighth Ann. Rep., Fishery Board for Scotland, p. 321, pl. xii., figs. 1, 2.

"Shell, seen from the side, semiovate, dorsal and ventral margins nearly parallel; dorsal margin a flattened curve, sloping downwards posteriorly, and forming with the nearly straight ventral margin a somewhat bluntly angular extremity; anterior end sharply rounded below, then curving obliquely upwards and backwards till it merges in the dorsal margin. Seen from above, the width is greatest near the anterior end, but varies little for about three quarters of the length, when the sides converge and form posteriorly a somewhat wedge-shaped extremity. The anterior end is broadly rounded, inclining to angular in the middle, where the valves meet; greatest breadth equal to height; height about one-third the length. Surface of the valves smooth, but having a slightly resinous appearance. Length, ·35 mm.

"*Habitat.*—Off St. Monica; not very rare. Specimens of this form have been dredged on several occasions at this place. Depth, 12–14 fathoms; bottom clear gravel and sand. The animal has not yet been made out; the species is therefore for the present doubtfully referred to *Cythere*."

We quote here the original description and give illustrations from one of Mr. Scott's specimens kindly lent to us for that purpose. We, however, think that the description is erroneous in taking the anterior for what is really the posterior extremity of the shell. It is a very minute form; but we do not recognise it as the young of any species known to us.

Cythere tuberculata (G. O. Sars).

Distribution.—Vadsö, shallow water; and tidemarks, Klosterelv Fiord, East Finmark (A. M. N.).

Cythere concinna, T. R. Jones.

Distribution.—Tidemarks and shallow water, Vadsö, Bog and Klosterelv Fiords, East Finmark (A. M. N.).

Cythere emarginata (G. O. Sars).

Distribution.—East Finmark, living between tidemarks and in shallow water, Vadsö and Klosterelv Fiords (A. M. N.).

Cythere finmarchica (G. O. Sars).

Distribution.—Vadsö and Lang Fiords, living between tidemarks and in shallow water (A. M. N.).

Cythere angulata (G. O. Sars).

Distribution.—East Finmark, living between tidemarks and in shallow water at Vadsö and in Klosterelv Fiord (A. M. N.).

Cythere mirabilis, G. S. Brady.

Distribution.—Living, Varanger Fiord, 125–150 fathoms, and Bog Fiord, 20–30 fathoms (A. M. N.).

Cythere dunelmensis, Norman.

Distribution.—East Finmark, tidemarks to 100 fathoms, Vadsö, Bog, and Klosterelv Fiords (A. M. N.).

Limnicythere inopinata (Baird).

(Pl. LXVIII., figs. 5, 6.)

1888. *Limnicythere incisa*, . . DAHL, "Die Cytheriden der westlichen Ostsee Zool. Jahrbüch." Bd. III., 1888, p. 20, pl. ii., figs. 49–58.

1890. ,, ,, . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," Christ. Videns-Selsk. Forhand., p. 69.

We give a figure of *Limnicythere incisa* received from Professor G. O. Sars. We regard it simply as a variety of *L. inopinata*.

Distribution.—G. O. Sars records both *L. inopinata* and *L. incisa* from Norway.

Limnicythere compressa, Brady & Norman.

1889. *Limnicythere inopinata*, . . Var. *compressa*. Brady & Norman, "Monog. Marine and Freshwater Ostracoda" (Trans. Roy. Dub. Soc., ser. 2, vol. iv.), p. 170, pl. xvii., figs. 18, 19.

We have come to the conclusion that this Ostracod must be regarded as distinct from *L. inopinata*, to which we had assigned it as a variety. We have now found it in a second locality. In both habitats the form is constant, and shows no approach to *L. inopinata*, from which it is at once distinguished by the much more gibbous central portion of the valves and more concave ventral margin, but especially by the extraordinary compression of the anterior and posterior extremities.

Habitat.—Whitefield Loch, Wigtonshire; Loch Aber, Kircudbrightshire (A. M. N.).

Limnicythere Sancti-Patricii, Brady & Robertson.

Distribution.—Norway (G. O. Sars).

Cytheridea(?) monensis, n. sp.

(Pl. lxviii., figs. 10, 11.)

Shell, seen from the side, subovate, greatest height equal to rather more than half the length, and situated near the middle; anterior extremity evenly rounded, posterior also well rounded, but narrower; dorsal margin sloping with a gentle curve towards the front, and in a slightly sinuated line backwards, the posterior angle being quite rounded away; ventral margin nearly straight. Seen from above, the outline is subcuneate, though not very much wider behind than in front, and the left valve overlaps the right at both extremities; greatest width at the posterior extremity, and equal to less than half the length; anterior extremity wide and rounded, with abruptly converging sides, mucronate in the middle; posterior subtruncate, the margin of each valve almost rectilinear, and meeting its neighbour at an obtuse angle. Surface of the shell covered with large, deeply impressed subrotund pittings; anterior border fringed below the middle with a series of short, bluntly rounded teeth, which form a sort of crenulated crescentic flange, the posterior ventral angle produced in a somewhat similar fashion, but with a smaller number of teeth, which are also more irregular, and give a marked prominence to the angle of the shell. Length, 0·65 mm.

One specimen only of this species was taken in a tide-pool at Port St. Mary, Isle of Man (G. S. B.). In general aspect, and more especially in its style of surface-sculpture, it is not unlike *Cythere marginata*, but it lacks the tubercular elevation over the anterior hinge-joint; the posterior ventral angle is prominent, while in *C. marginata* that part is much cut away, and the outline, as seen from above, is altogether different. On the hinge-line there is an appearance of crenulation, which, together with the general outline of the shell, leads us to refer the species provisionally to the genus *Cytheridea*.

Cytheridea papillosa, T. R. Jones.

Distribution.—East Finmark, common (A. M. N.).

Cytheridea punctillata, G. S. Brady.

Distribution.—Vadsö; Lang, Bog, and Klosterelv Fiords, in 5–100 fathoms (A. M. N.).

Cytheridea Sorbyana, T. R. Jones.

Distribution. — Fine living examples in Klosterelv Fiord, East Finmark, 5 fathoms (A. M. N.).

Eucythere declivis (Norman).

Distribution.—In 0–25 fathoms, together with var. *Argus*, G. O. Sars; East Finmark (A. M. N.).

Krithe bartonensis, T. R. Jones.

Distribution.—Vadsö, in 5–15 fathoms.

Loxoconcha tamarindus, T. R. Jones.

Distribution.—Living between tidemarks and in shallow water, Vadsö and Klosterelv Fiord (A. M. N.).

Loxoconcha fragilis, G. O. Sars.

Distribution.—A single living specimen between tidemarks in Klosterelv Fiord (A. M. N.).

Xestoleberis depressa, G. O. Sars.

Distribution.—East Finmark, common (A. M. N.).

Cytherura affinis, G. O. Sars.

Distribution.—Shallow water, Vadsö; and tidemarks, Klosterelv Fiord (A. M. N.).

Cytherura sella, G. O. Sars.

Distribution.—Vadsö, 20–30 fathoms (A. M. N.).

Cytherura undata, G. O. Sars.

Distribution.—0–25 fathoms, East Finmark, in several places (A. M. N.).

Cytherura grœnlandica, Brady & Norman.

Distribution.—Vadsö, in 5–25 fathoms; new to Europe (A. M. N.).

Cytherura similis, G. O. Sars.

Distribution.—Vadsö, with the last (A. M. N.).

Cytherura mucronata, T. Scott.

(Pl. lxiii., figs. 18, 19.)

1890. *Cytherura mucronata*, . . Scott, T., "Additions to the Fauna of the Firth of Forth," Eighth Ann. Rep. Fishery Board for Scotland, p. 323, pl. xii., figs. 3–5.

"Shell, seen from the side, elongate, narrow; height about equal at both ends, length two and a-half times the height; dorsal margin nearly straight, ventral margin slightly and evenly concave, posterior end much produced, and wedge-shaped, forming a 'beak,' which is situated below the middle; anterior margin broadly rounded, somewhat produced in the middle. Seen from above, oval, with the ends acuminate; the margin at each end, especially at the anterior, is produced so as to form a distinct 'mucro.' The surface is marked with indistinct raised lines, which are somewhat irregularly distributed; the breadth is equal to the height. Length, ·33 mm."

Habitat.—Off St. Monace; not very rare.

We figure one of Mr. Scott's specimens, but believe that it must be referred to the young of *Cytherura producta*, Brady.

Cytherura bodotria, T. Scott.

(Pl. xiv., figs. 16, 17.)

1890. *Cytherura bodotria*, . . Scott, T., "Additions to the Fauna of the Firth of Forth," Eighth Ann. Rep. Fishery Board for Scotland, p. 322, pl. xii., figs. 6, 7.

"Shell, seen from the side, of nearly equal height throughout; dorsal and ventral margins nearly straight, the former is slightly convex towards the anterior extremity; anterior margin evenly rounded, posterior extremity with a short

beak situated about the middle, its termination narrow, truncate. Seen from above, ovate, slightly constricted in front, where the valves meet. At the posterior end the middle is bluntly mucronate, and the sides are produced to an acute angle, so as to impart to it a somewhat tridentate appearance; dorsal ridge prominent, where it bends downwards in front. Surface sculptured with flexuous longitudinal riblets, crossed by a few indistinct ones arranged irregularly. Length, ·5 mm.; breadth, three-fifths the length; height, fully one-third the length.

"*Habitat.*—Off St. Monace, in 12 to 14 fathoms; bottom sand and gravel rare.

"This species somewhat resembles *Cytherura acuticostata*, but differs in being not so stout, and in having the valves produced backwards, so that the posterior extremity of the shell has a tridentate form."

We figure Mr. Scott's type specimen, which he has kindly sent to us for that purpose. We believe that it must be regarded as the young of *Cytherura acuticostata*. We have not a series down to the very young of that species; but in the young of the genus *Cytherura* the beak occupies a much larger proportion of the shell, and is thus more prominently conspicuous than in the adult. We have especially noticed this to be the case in *C. cornuta* and *C. nigrescens;* and a very fine series of the young of the former species shows that the lateral projections are also more acute in the young than in the adults. We figure the young of the two last-mentioned species in illustration of our remarks (Pl. LXIII., figs. 20, 21.)

Cytherura nigrescens (Baird).

Distribution.—East Finmark, tidemarks (A. M. N.).

Cytherura rudis, G. S. Brady.

Distribution.—Entrance of Vadsö Harbour, in 15–25 fathoms; new to Europe. (A. M. N.).

Cytherura cellulosa (Norman).

Distribution.—Vadsö, 20–30 fathoms.

Cytheropteron latissimum (Norman).

Distribution.—East Finmark, in 0–25 fathoms (A. M. N.).

Cytheropteron nodosum, G. S. Brady.

Distribution.—A single specimen, Vadsö, 15–25 fathoms (A. M. N.).

Bythocythere constricta, G. O. Sars.

Distribution.—Vadsö, tidemarks (A. M. N.).

Bythocythere recta, G. S. Brady.

Distribution.—One small living specimen dredged in 20 fathoms to the east of Vadsö, Finmark (A. M. N.).

Pseudocythere caudata, G. O. Sars.

Distribution.—Vadsö, in 5–15 fathoms (A. M. N.).

Paradoxostoma variabile (Baird).

Distribution.—Tidemarks, Vadsö and Klosterelv Fiord (A. M. N.).

Paradoxostoma rostratum, G. O. Sars.

Distribution.—Three specimens among weeds between tidemarks, at Vadsö (A. M. N.).

Paradoxostoma inflexum, Brady & Norman.

(Pl. lxiii., figs. 12, 13.)

1891. *Paradoxostoma inflexum*, . . Brady & Norman, "In Norman Marine Crustacea Ostracoda of Norway," Ann. and Mag. Nat. Hist., ser. 6, vol. vii., p. 118, and woodcut.

Shell, seen from the side, siliquose, greatly curved, greatest height equal to two-fifths of the length, behind the middle; anterior half of much less height than the posterior, and bending downwards; anterior extremity narrow, but well and evenly rounded; dorsal margin strongly arched throughout, without any angularity in any part, posterior declination much more sudden than the anterior; ventral margin deeply concave in front of the middle, behind the middle gently convex, the hinder portion of the shell thus becoming much higher than the anterior. Seen from above, very narrow, greatest width not more than half the height, sides nearly flat, both extremities very narrow, but the anterior more acute than the posterior. Length, ·4 mm.

Tidemarks, among weeds, Vadsö, East Finmark (A. M. N.).

There are only two Ostracoda which this very small species can be said to approach at all in shape, and of which it might be suggested that it was the young. These are *Paradoxostoma Normani* and *Sclerochilus contortus*. With the young of the same size in these species it has been compared, and it differs *in toto*. The young of the first of these species is very much shorter and higher, in fact shorter and higher than the adult, and less incurved. The young of *Sclerochilus*

contortus is very nearly of the same shape as the adult, the extremities much more nearly equal than in this species, and consequently the whole shape different; it is also more tumid. It is possible that the present species may hereafter prove to be a *Sclerochilus* and not a *Paradoxostoma*. The specimens described had been dried before they were noticed, though living when collected.

Paradoxostoma (?) **affine**, T. Scott.

(Pl. LXIII., figs. 10, 11.)

1890. *Paradoxostoma*(?) *affine*, . . Scott, T., "Additions to the Fauna of the Firth of Forth," Eighth Ann. Rep. Fishery Board for Scotland, p. 325, Pl. xii., figs. 8, 9.

Shell, seen from the side, elongate, subovate, highest a little behind the middle; dorsal margin evenly but not boldly arched, inferior nearly straight, slightly sinuate towards the anterior extremity; anterior extremity rather higher than the posterior, and the margins of both evenly rounded; surface smooth, with a few irregular scratched lines. Outline, seen from above, compressed, ovate, the posterior half of nearly equal breadth, with the extremity obtusely pointed. Anteriorly the shell is more compressed, the extremity being somewhat acuminate; breadth about equal to height, and one-third the length. Length, ·42 mm.

The form resembles a small *P. arcuatum*, but is not so narrow posteriorly, and the greatest breadth is nearer the posterior extremity. It seems to us, however, to resemble even more closely the genus *Aglaia*, and quite possibly may be the young of *A. complanata*. Our figures are taken from one of Mr. Scott's specimens.

Habitat.—Off St. Monace; not common (T. Scott); Inverary 25–40 fathoms (A. M. N.).

Paradoxostoma flexuosum, G. S. Brady.

This appears to be a species of remarkable variability, and it seemed to us right after examination of a very large number of specimens from various localities to unite *P. tenerum*, B. C. & R., with it. Perhaps more than one species is confused under the name *P. flexuosum*.

Genus **Cytherois**, W. Müller.

G. O. Sars removes his *Paradoxostoma vitreum* into the genus *Cytherois*.

WORKS AND PAPERS CONSULTED IN THE PREPARATION OF THIS MONOGRAPH.

(*Addenda to List in Vol.* iv., *pp.* 258–264.)

Bennie (J.) and Scott (T.):

"The Ancient Lakes of Edinburgh."—Proc. Roy. Phys. Soc. Edinburgh, vol. x., 1889, pp. 126–154.

Brady (G. S.):

"On Ostracoda collected by H. B. Brady, Esq., in the South Sea Islands."—Trans. Roy. Soc. Edinb., vol. xxxv., 1890, pp. 489–525.

Claus (C.):

"Elementary Text-Book of Zoology," 1884, vol. i., pp. 423–428.

"Schriften zoologischen Inhalts. 1. Die Familie der Halocypriden," 1874, pp. 1–16, pls. i.–iii.

"Untersuchungen zur Erforschung der genealogischen Grundlage des Crustaceen-Systems," 1876, pp. 91–100, pls. xvii., xviii.

"Ueber die Organisation der Cypriden."—Kais. Akad. d. Wiss. Wien., 20. März, 1890, pp. 1–6. Translated, Ann. and Mag. Nat. Hist., ser. 6, vol. vi., p. 108.

"Die Halocypriden des atlantischen Oceans und Mittelmeeres," 1891.

"Beiträge zur Kenntniss der Süsswasser-Ostracoden."—Arbeiten z. Institut. Wien., vol. ix., 1892, pp. 147–216.

"Bemerkungen über marine Ostracoden aus den Familien der Cypridinen und Halocypriden."—Arb. z. Inst. Wien, vol. viii., 1888, pp. 149–154.

Croneberg (A.):

"Beitrag zur Ostracoden-Fauna der Umgegend von Moskau."—Bull. Soc. Imper. des Naturalistes de Moscou, 1894, 23 pages, pl. vii.

Dana (J. D.):

"Conspectus Crustaceorum, quæ in orbis terrarum circumnavigatione C. Wilks" (text).—Proc. American Acad. of Arts and Science, vol. ii., 1849 (read, published 1852?), pp. 49–53 (separate copy).

Gerstacker (A.):

In Bronn "Die Classen und Ord. des Thierreichs: Bd. v., Arthropoda. 1. Hälfte, Crustacea.," 1866–1870, pls. xxvi.–xxviii.

Grube (A. E.):

"Ein Ausflug nach Triest und dem Quarnero," 1861, pp. 92–107, pl. v. (*Cypridina oblonga*).

Guerne (Baron Jules de):

"Un Ostracode nouveau pour la faune française. La distribution géographique de *Cypris bispinosa*."—Bulletin de la Soc. Entomologique de France, 1892.

Hesse (E.):

"Desc. des Crust. rares ou nouveaux des cotes de France. Vingt-huitième article: Description de nouveaux Crustaces de la légion des Branchiopodes, de l'ordre des Cladocères, formant la nouvelle famille des Copéchétiens, et le nouveau genre Copechœte."—Ann. Sci. Nat. Zool., ser. 6, vol. vii., pp. 1–20 (separate copy), pl. xii.

Kaufmann (A.):

"Beiträge zur Kenntniss der Cytheriden," 1886.

"Ueber die Gattung Acanthopus und eine neue Süsswasser-Cytheride."—Zool. Anz., vol. xv., 1892, pp. 393–395.

Kertész (Kolman):

"Daten zur Ostracoden-Fauna der Umgegend Szeghalom's."—Természetrajzi Füzetek, 1893, p. 169, pl. vi.

Moniez (R.):

"Quelques Cladocères et sur un Ostracode nouveaux du Lac Titiaca."—Revue Biolog. du Nord de la France, vol. i., 1889.

"Pêches de M. A. Dollfus en quelques points de la France et de la Hollande."—Bull. Soc. d'études scientifiques de Paris, 1889.

"Faune des caux souterraines du Department du Nord."—Revue Biol. du Nord de la France, 1889, p. 179.

"Faune des Lacs Salés d' Algerie."—Mem. de la Soc. Zool. de France, vol. iv., 1891, p. 246–257.

"Les Mâles chez les Ostracodes d'eau douce."—Revue Biol. du Nord de la France, vol. iii., 1891, Abstract, Jour. Roy. Micros. Soc., 1891, p. 346.

"Entomostracés d'eau douce de Sumatra et de Celebes: II. Ostracodes."—Zool. Ergebn. e. Reise in Niederl. Ost.-Ind., vol. ii., pp. 129–135.

Mrázek (A.):

"O cysticerkoldeck našich korýšů sladkovodnícк."—Veštník Král. České společnosti nauk., 1890, pls. v., vi.

Müller (G. W.):

"Neue Cypridiniden."—Zoologische Jahrbüchern, vol. v., 1890, pp. 211–252, pls. xxv.–xxvii.

"Ueber Halocypriden."—Zoologische Jahrbüchern, vol. v., 1890, pp. 253–280, pls. xxviii., xxix.

"Ueber Lebensweise und Entwicklungsgeschichte der Ostracoden."—Sitz. der Köng. Preuss. Akad. der Wiss. zu Berlin, vol. xxiii., 1893, pp. 1–27.

"Die Spermatogenese der Ostracoden."—Zoolog. Jahrbüch., vol. iii., Abth. f. Morph., p. 677–726, pls. xxxii., xxxiii.

"Fauna und Flora des Golfes von Neapel.—Die Ostracoden," 1894.

Norman (A. M.):

"Notes on the Crustacea Ostracoda of Norway."—Ann. & Mag. Nat. Hist., ser. 6, vol. vi., 1891, pp. 108–121.

Philippi (O.):

"Einige zoologische Notizen. II."—Archiv. f. Naturges., 1840, p. 188. (Translated, Ann. & Mag. Nat. Hist., vol. vi., 1840, p. 94.)

Rehberg (H.):

"Beit. z. Naturges. niederer Crustaceen."—Inaug. Dissert. Abhandlg., heraus. vom naturw. Vereine zu Bremen, vol. ix.

Robertson (D.):

"On some recent Ostracoda dredged in Granton Harbour."—Proc. Nat. Hist. Soc. Glasgow, vol. iii., 1892, pp. 196–198.

Rosseter (J. B.):

"On the Male Generative Organs of two species of Cypris (*C. cinerea* and *C. minuta.*)"—Jour. Microscopy and Natural Science, 1888, pp. 231–239.

Sars (G. O.):

"Some Freshwater Ostracoda and Copepoda raised from Dried Australian Mud."—Videns.-Selsk. Förhand. Christiania, 1889, pp. 1–58, pls. i.–vi.

"Oversigt af Norges Crustaceen: II. Branchiopoda, Ostracoda, Cirripedia."—Christ. Videns-Selsk. Förhand, 1890, pp. 1–90.

"Contributions to the knowledge of the Freshwater Entomostraca of New Zealand, as shown by artificial hatching from dried mud."—Vidensk.-Selsk. Skrif., 1895, pp. 1–62, pl. i.–viii.

Scott (T.):

"Revised List of the Crustacea of the Firth of Forth."—Sixth Annual Report Fishery Board for Scotland, 1888, pp. 242–245.

"Some additions to Fauna of Firth of Forth, with Notes on some rare East Coast Forms."—Seventh Annual Report Fishery Board for Scotland, 1889, pp. 316–319.

"Invertebrate Fauna of Inland Waters, I. Report on Loch Coulter and the Coulter Burn, Stirlingshire."—Eighth Annual Report Fishery Board for Scotland, 1889, pp. 334–347.

"Additions to the Fauna of the Firth of Forth."—Eighth Annual Report of the Fishery Board for Scotland, 1889, pp. 320–325, pl. xii.

"Notes on Small Collection of Freshwater Ostracoda from the Edinburgh District."—Proc. Roy. Phys. Soc. Edinburgh, vol. x., 1891, pp. 313–317.

"Preliminary Note on a Post-Tertiary Freshwater Deposit at Kirkland, Leven, and at Elie, Fifeshire."—Proc. Roy. Phys. Soc. Edinburgh, vol. x., 1891, pp. 334–345.

"The Invertebrate Fauna of the Inland Waters of Scotland," Pt. ii.—Ninth Annual Report, Fishery Board for Scotland, 1891, pp. 269–296.

"Additions to the Fauna of the Firth of Forth."—Ninth Annual Report, Fishery Board for Scotland, 1891, p. 307. *Cythere gibbosa* is the only addition to the Ostracoda of the Firth of Forth in this paper.

"Some freshwater, brackishwater, and marine Entomostraca new to the Fauna of Orkney."—Trans. Nat. Hist. Soc. Glasgow, 1891, pp. 91–100.

Scourfield (D. J.):

"The Entomostraca of Wanstead Park."—Journ. Quekett Micros. Club, ser. 2, vol. v., 1893, pp. 161–178.

Šostaric (D.):

"Prilog poznavanju faune slatkovodnik korepnjaka hrvatsche."—Preŝtampano iz xcii knjige Bada iugoslavenske akademije znanosti i umjetnosti. U. Zagrebu, 1888.

Turner (C. H.):

"Notes upon the Cladocera, Copepoda, Ostracoda, and Rotifera of Cincinnati, with Descriptions of New Species."—Bulletin of the Scientific Laboratories of Denison University, vol. vi., pt. II., pp. 57–74, pls. i., ii., 1892.

"Additional Notes on the Cladocera and Ostracoda of Cincinnati, Ohio."—*Ibidem*, vol. viii., pt. I., pp. 3–18, pl. i., ii., 1893.

Vávra (V.):

"Kritisches Verzeichniss der Ostracoden Böhmens."—Sitzungsb. der Königl. böhm. Gesells. der Wiss., 1891, pp. 159–163.

"Ueber das Verkommen einer Süsswasser-Cytheride in Böhmen."—Zoologischer Anzeiger, No. 357, 1891.

"Monographie der Ostracoden Böhmens."—Archiv. der Naturwiss. Landesdurchforschung von Böhmen, vol. viii., 1891.

Vejdovsky (F.):

"Thierische Organisation der Brunnenwasser v. Prag," 1882, pl. 8.

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EXPLANATION OF PLATE L.

PLATE L.

Asterope mariæ.

Figure

1. Animal (male), seen from right side ; right valve removed, × 50.

a., . . . Antennule.
b., . . . Basal portion of antenna.
c., . . . Swimming branch of antenna.
d., . . . Secondary branch of same.
e., . . . Mandibular foot.
f., . . . First maxilla.
g., . . . Second maxilla.
h., . . . Third maxilla.
i., . . . Caudal lamina.
k., . . . Branchiæ.
l., . . . Vermiform limb.
m., . . . Intestine.
n., . . . Male copulative organ.
o., . . . Vas deferens.
p., . . . Heart.
r., . . . Eye.

2. Antennule of male.

3. ,, female (secondary branch abnormal).

4. Antenna of male.

5. ,, female.

6. Mandibular foot of female. 6*a*. One of the tridentate setæ more highly magnified.

Asterope teres.

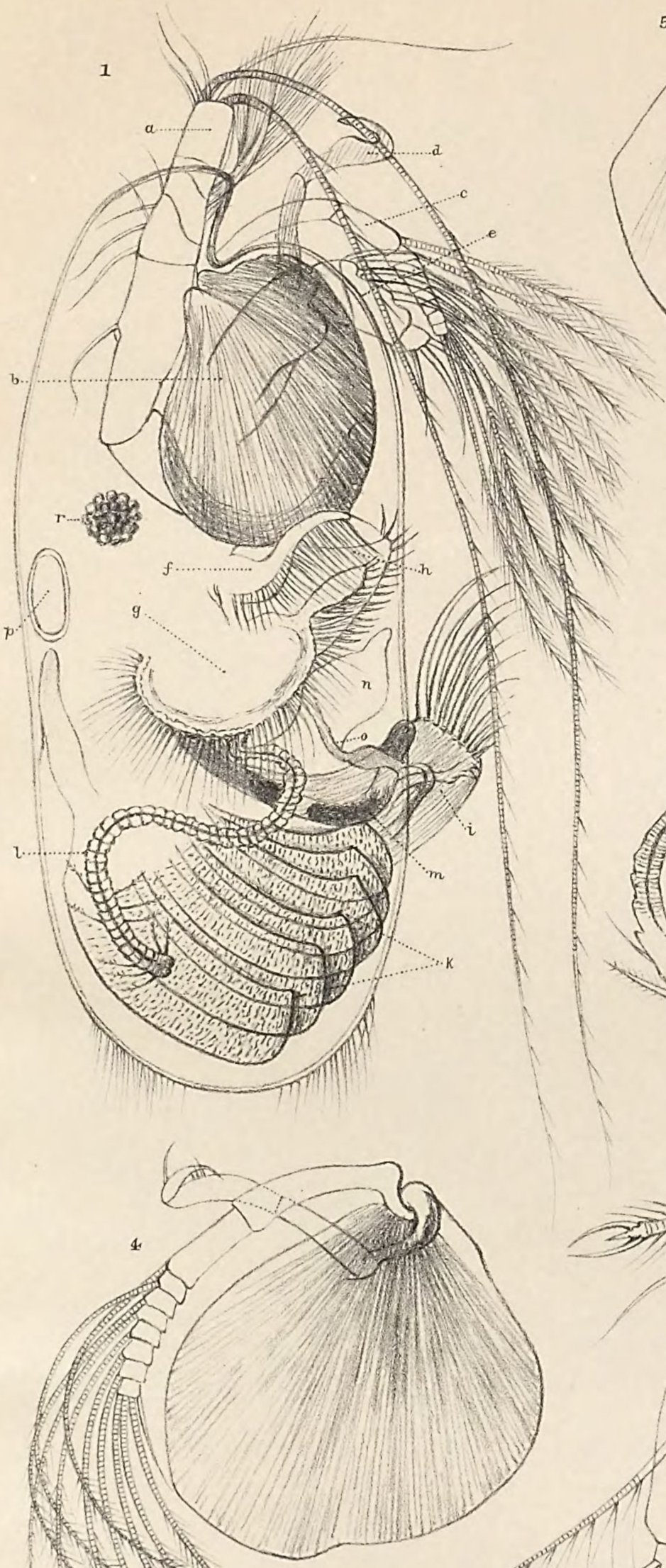
7. Secondary branch of antenna of female.

8. Antennule of female.

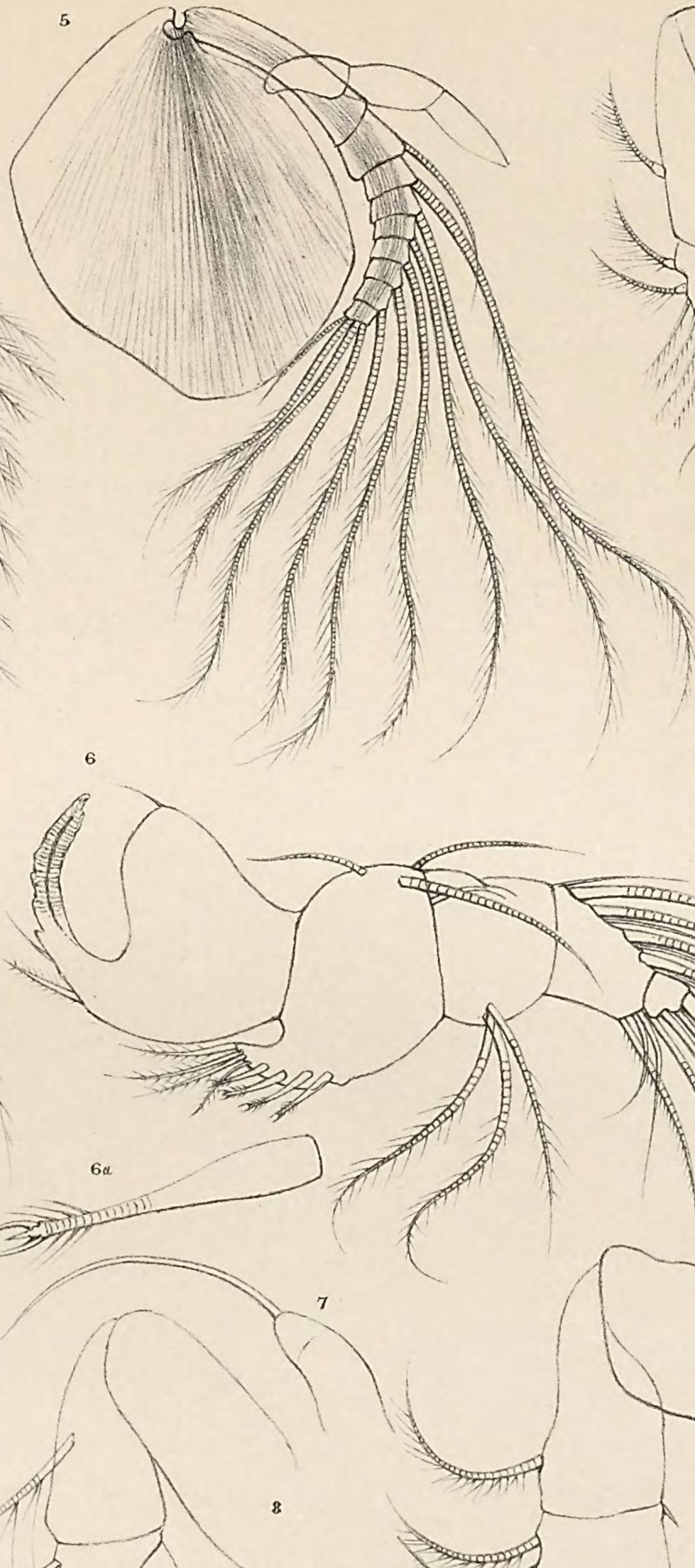
9. Seta of mandibular foot.

10. Secondary branch of antenna of male.

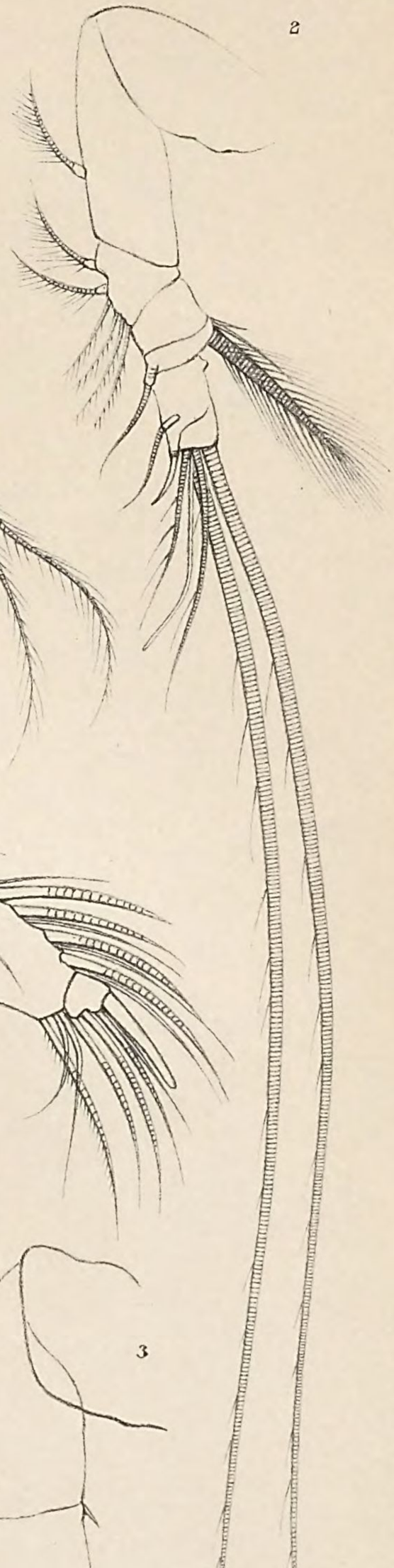
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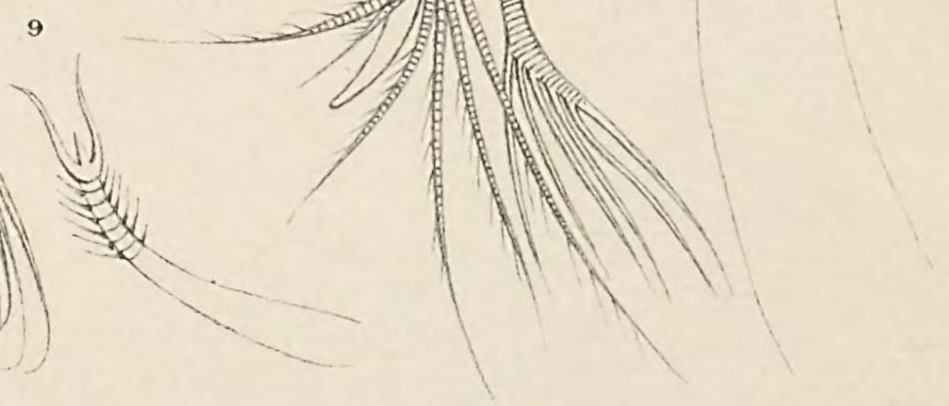
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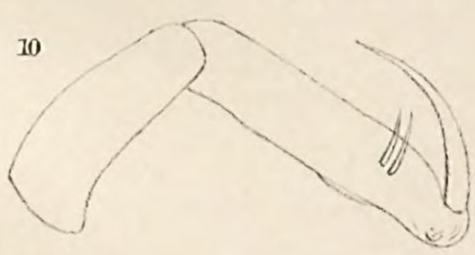
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EXPLANATION OF PLATE LI.

PLATE LI.

Figure

1. *Philomedes brendà*, male, secondary branch of antenna.
2. ,, ,, vermiform appendage.
3. ,, ,, spine of vermiform appendage.
4. ,, *Lilljeborgii*, male, seen from left side. × 30.
5. ,, ,, ,, secondary branch of antenna.
6. ,, ,, female, secondary branch of antenna.
7. ,, *Macandrei*, female, secondary branch of antenna.
8. ,, ,, spine of vermiform limb.
9. ,, *Folini*, male, seen from left side. × 16.
10. ,, ,, female, secondary branch of antenna.
11. *Asterope mariæ*, male, frontal tentacle.
12. ,, ,, ,, secondary branch of antenna.
13. ,, ,, ,, mandibular foot.
14. ,, ,, maxilla of first pair.
15. ,, ,, distal portion of same.
16. ,, ,, maxilla of second pair.
17. ,, ,, ,, third pair.
18. ,, ,, portion of vermiform limb.
19. ,, ,, spine of same more highly magnified.
20. ,, ,, copulatory organs.
21. ,, ,, one of the branchial laminæ.
22. ,, ,, caudal laminæ.



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EXPLANATION OF PLATE LII.

PLATE LII.

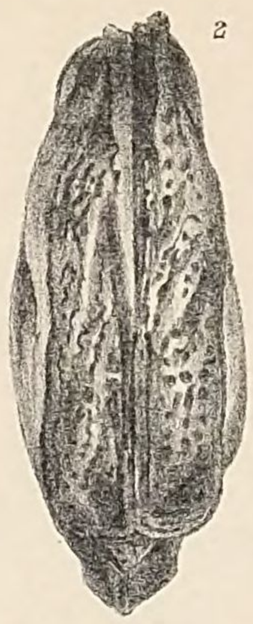
Figure

1. *Nematohamma obliqua*, seen from left side, ... × 40.
2. ,, ,, ,, ,, above, ... × 40.
3. *Philomedes Lilljeborgii*, female, seen from left side, . . . × 25.
4. ,, ,, ,, ,, ,, above, . . . × 25.
5. ,, *Macandrei*, ,, ,, ,, left side, . . . × 25.
6. ,, ,, ,, ,, ,, below, . . . × 25.
7. *Asterope norvegica*, male, seen from left side, . . . × 25.
8. ,, ,, female, ,, ,, ,, . . . × 25.
9. ,, ,, ,, ,, ,, below, . . . × 25.
10. ,, *mariæ*, small specimen, seen from right side, . . × 25.
11. ,, ,, male, seen from below, . . . × 25.
12. ,, ,, male, ,, ,, left side, . . . × 25.
13. ,, ,, ,, ,, ,, below, . . . × 25.
14. ,, ,, female, ,, ,, left side, . . . × 20.
15. ,, ,, ,, ,, ,, below, . . . × 20.
16. ,, *elliptica*, ,, ,, ,, left side, . . . × 30
17. ,, ,, ,, ,, ,, below . . . × 30.
18. ,, *abyssicola*, ,, ,, ,, left side, . . . × 30.
19. ,, ,, ,, ,, ,, below, . . . × 30.
20. ,, *teres*, ,, ,, ,, left side, . . . × 35.
21. ,, ,, ,, ,, ,, below, . . . × 35.

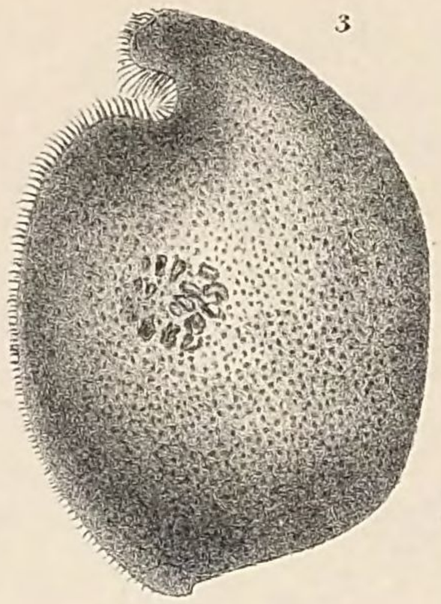
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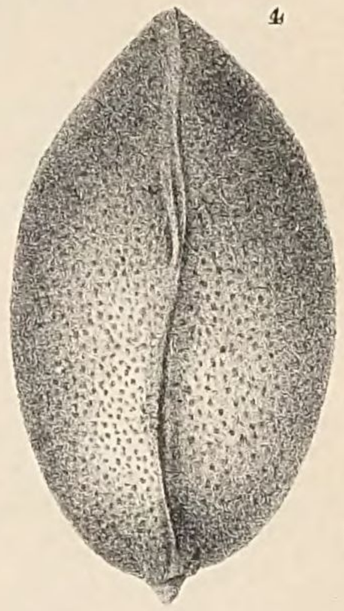
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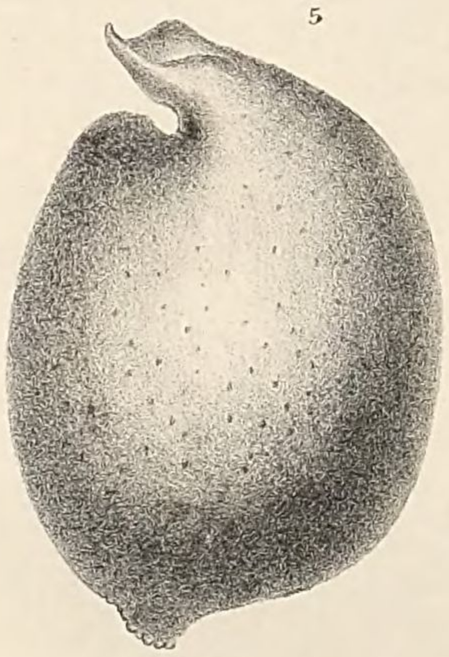
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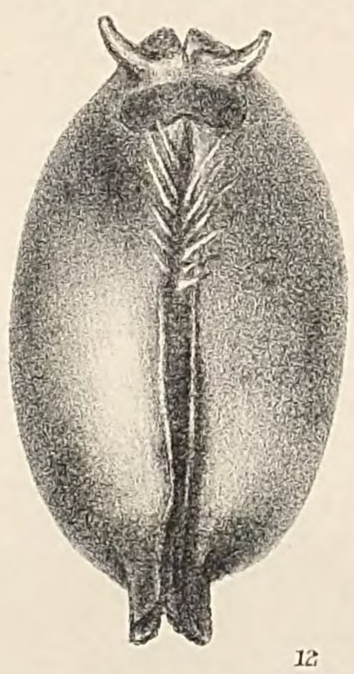
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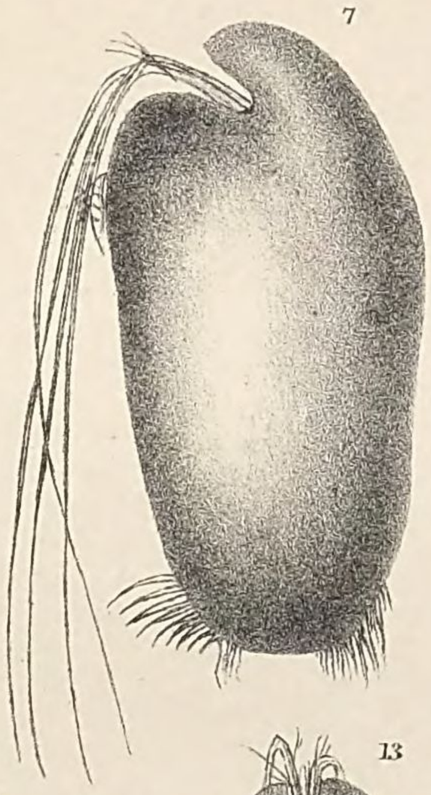
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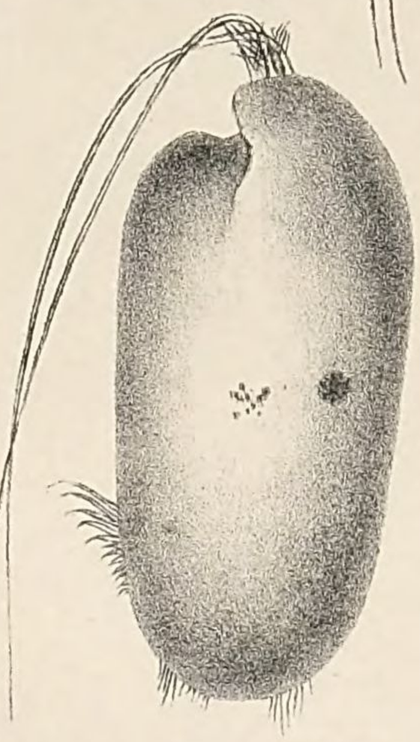
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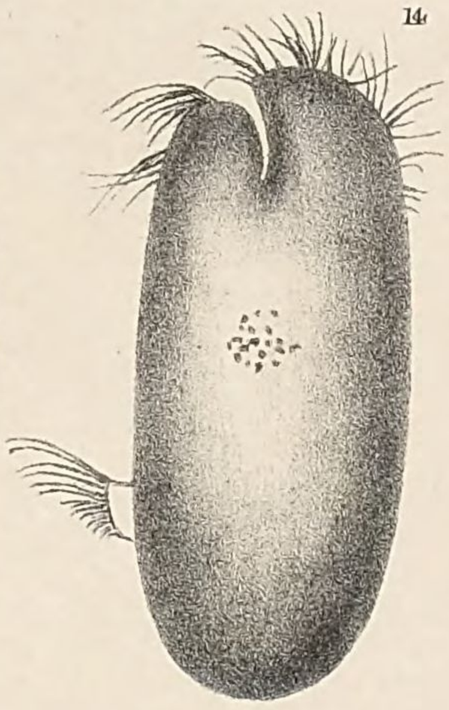
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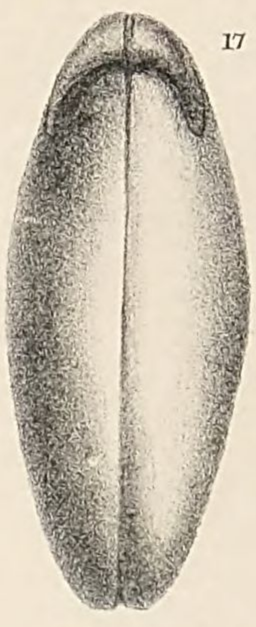
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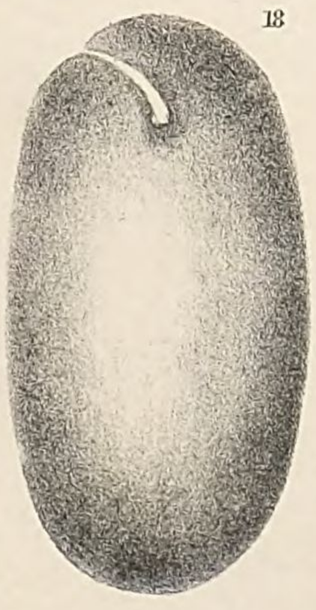
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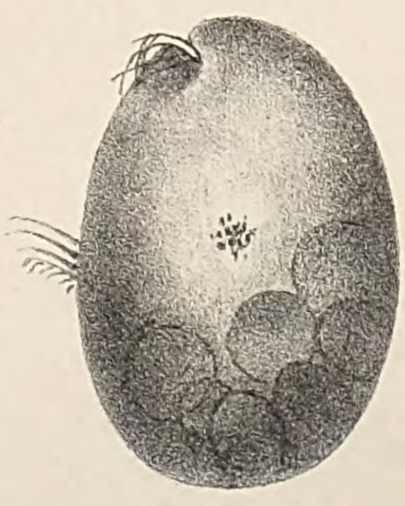
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EXPLANATION OF PLATE LIII.

PLATE LIII.

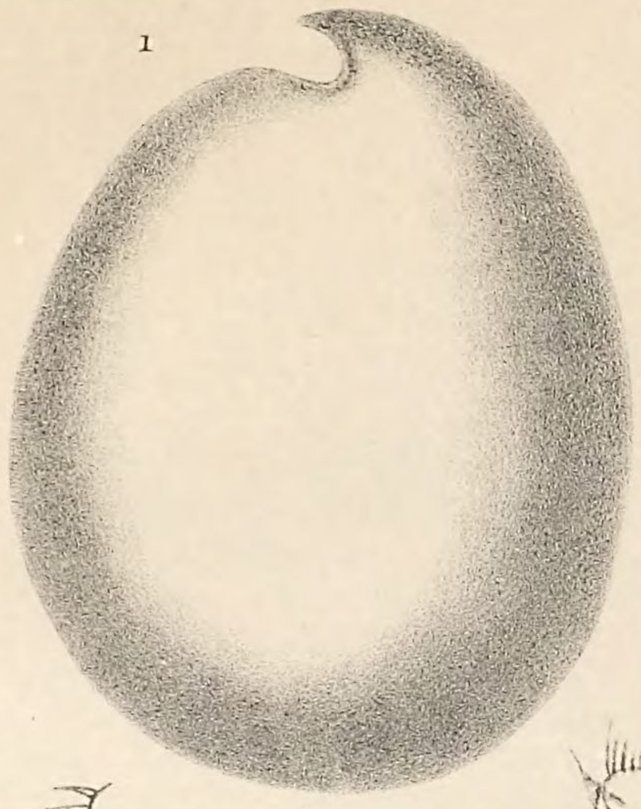
Crossophorus imperator, female.

Figure

1. Left valve, seen from side. × 12.
2. Antennule.
3. Secondary branch of antenna.
4. Mandibular foot ; *a*, one of the masticating spines more highly magnified.
5. Maxilla of first pair.
6. ,, second pair ; *a. b.*, ungues more highly magnified.
7. ,, third pair.
8. Apex of vermiform limb.
9. One of the lateral setæ of the same.
10. Caudal lamina.
11. Secondary branch of antenna of male. (Copied from Report of "Challenger" Expedition.)

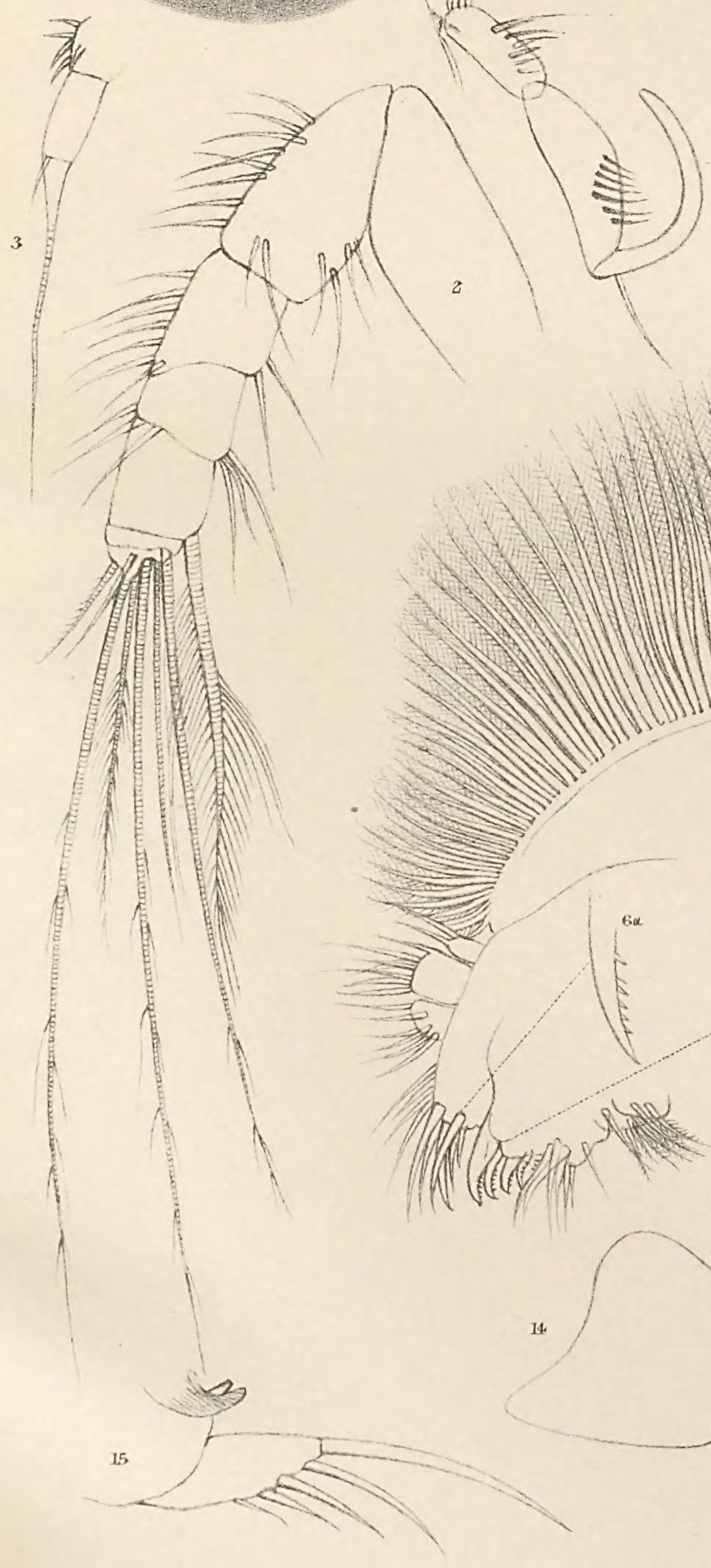
Nematohamma obliqua.

12. Antennule.
13. Secondary branch of antenna.
14. Mandibular foot.
15. Caudal lamina and copulatory organ.


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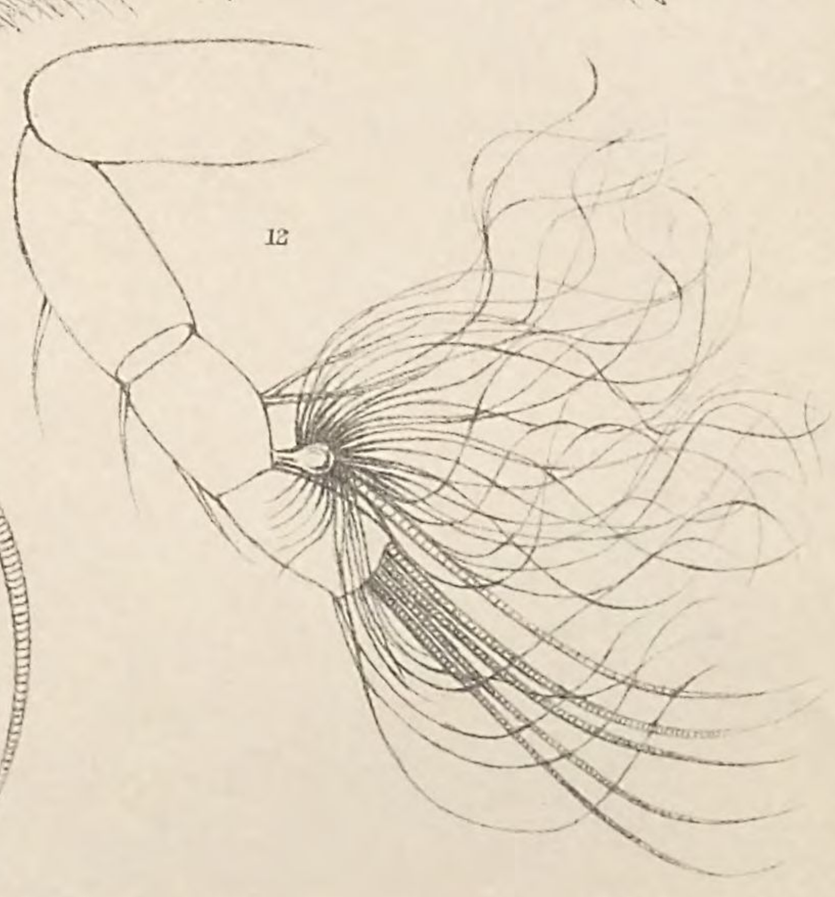
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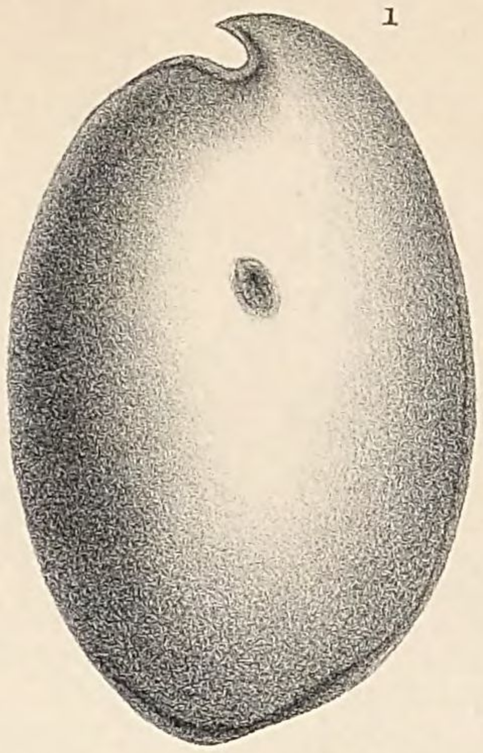
EXPLANATION OF PLATE LIV.

PLATE LIV.

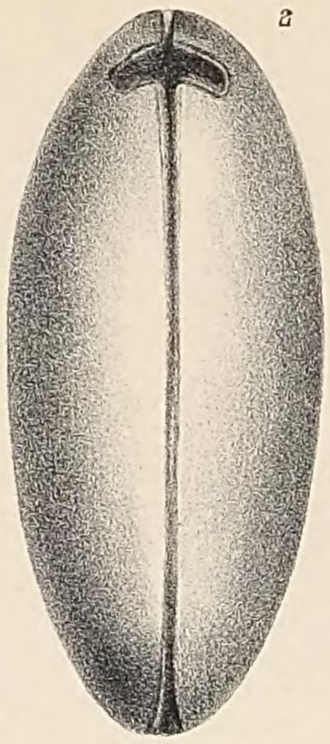
Figure

1. *Cypridina mediterranea*, seen from left side, ... × 22.
2. ,, ,, ,, ,, below, ... × 22.
3. ,, ,, ,, ,, left side, ... × 22.
4. ,, ,, ,, ,, above, ... × 22.
5. ,, *megalops*, ,, ,, left side, ... × 25.
6. ,. ,, ,, ,, below, ... × 25.
7. ,, *norvegica*, ,, ,, left side, ... × 16.
8. ,, ,, ,, ,, below, ... × 16.
9. *Polycope orbicularis*, ,, ,, right side, ... × 84.
10. ,, ,, ,, ,, above, ... × 84.
11. *Polycopsis compressa*, ,, ,, left side, ... × 84.
12. ,, ,, ,, ,, above, ... × 84.

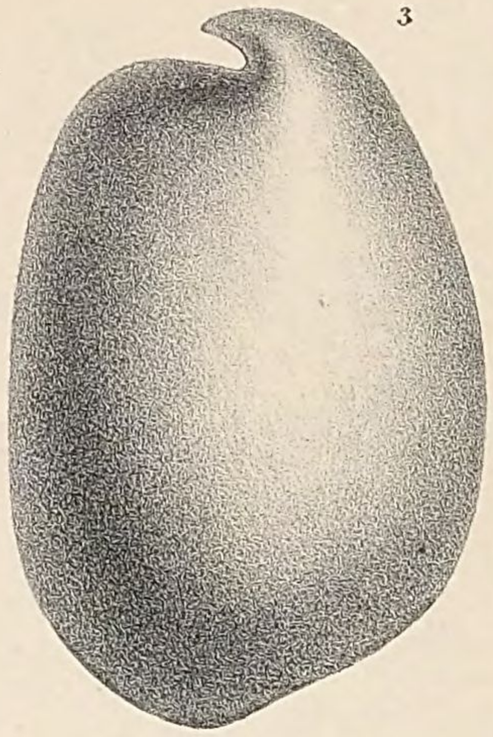
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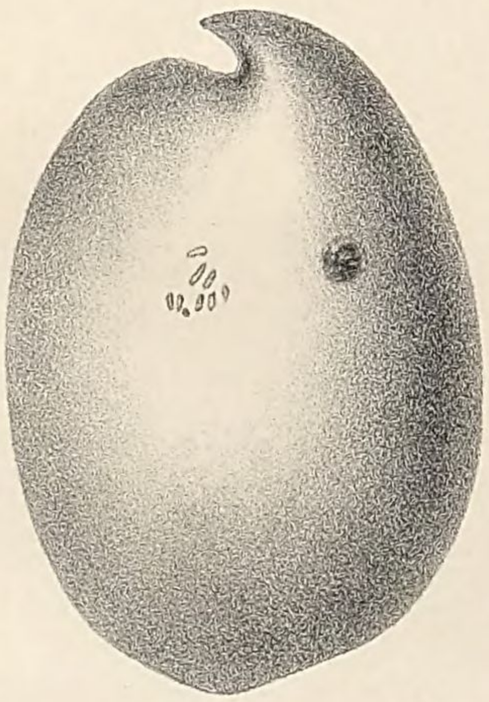
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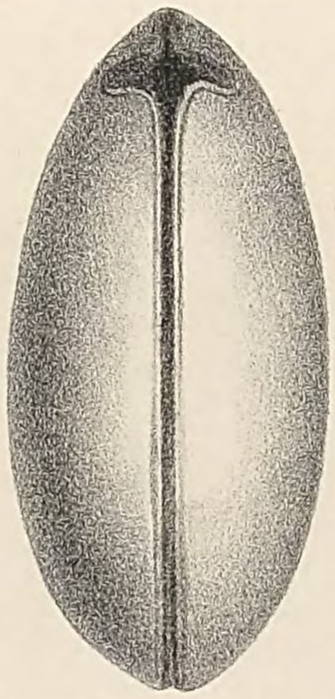
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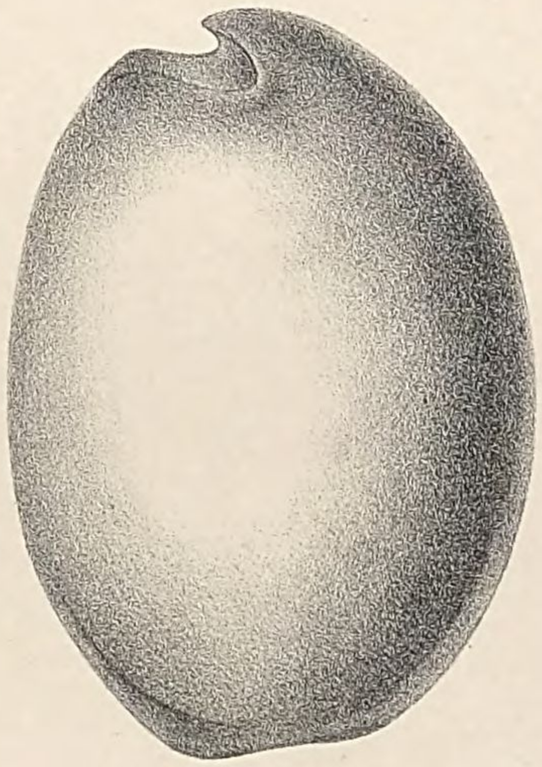
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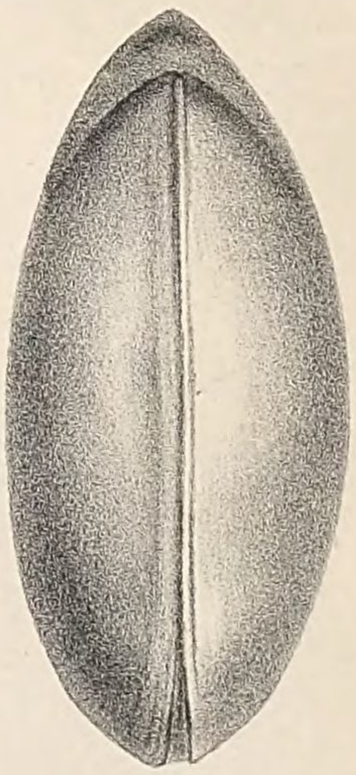
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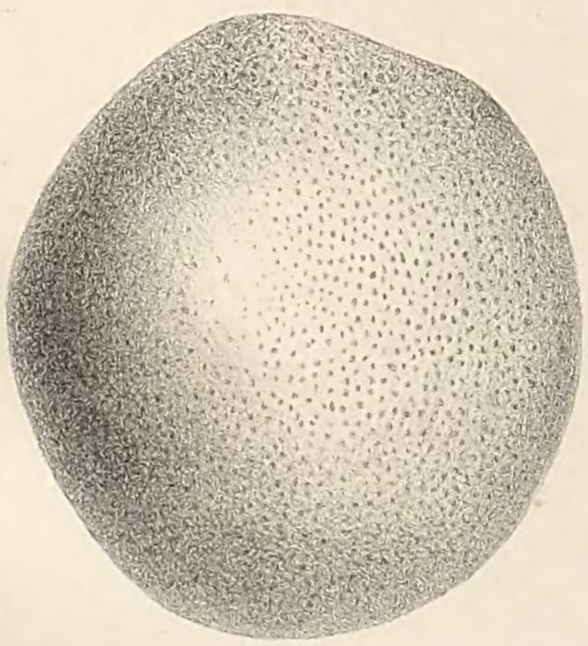
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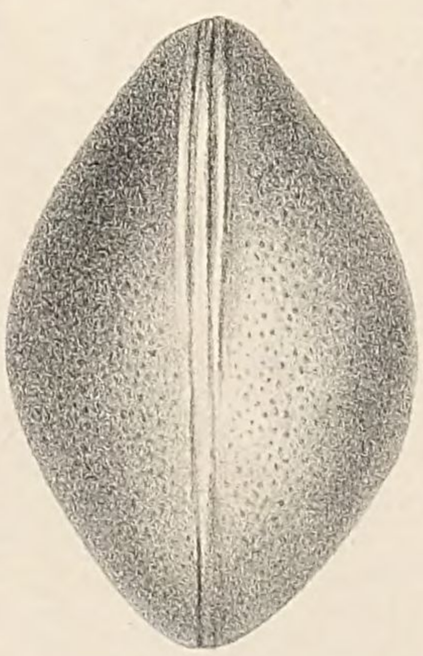
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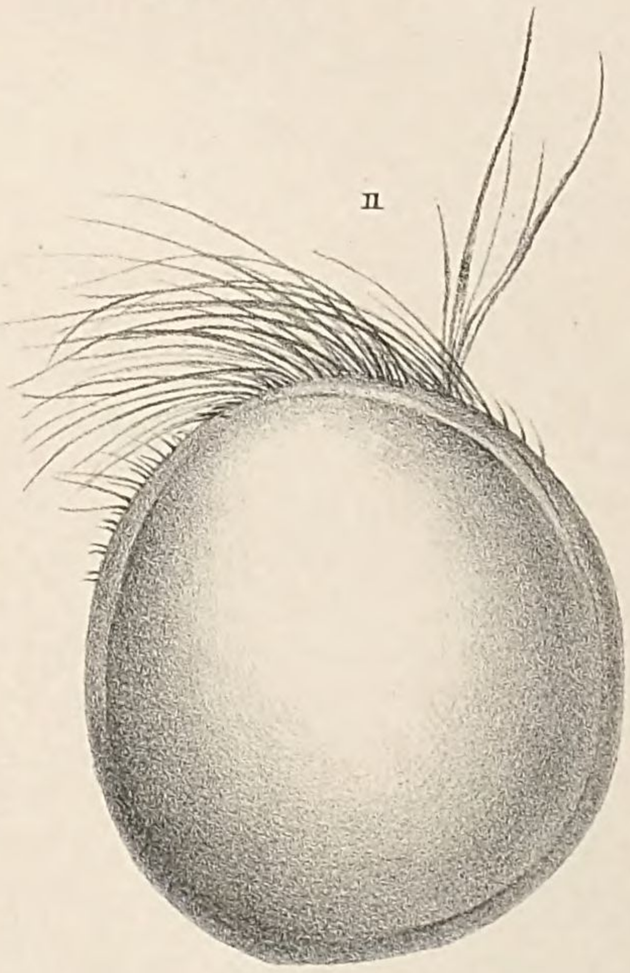
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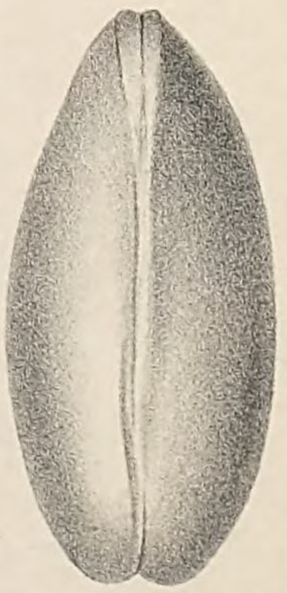
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EXPLANATION OF PLATE LV.

PLATE LV.

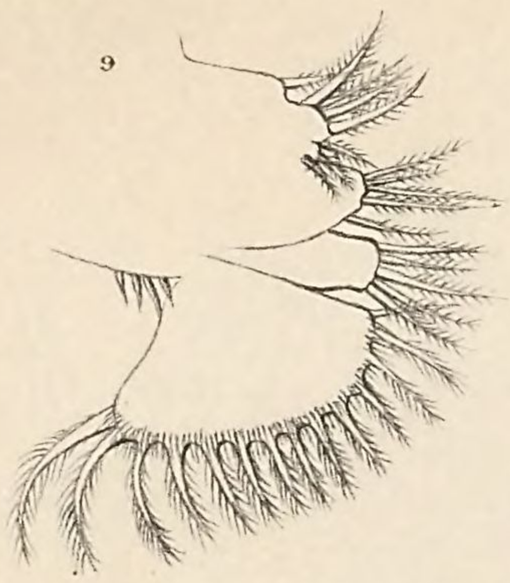
Cypridina mediterranea, female.

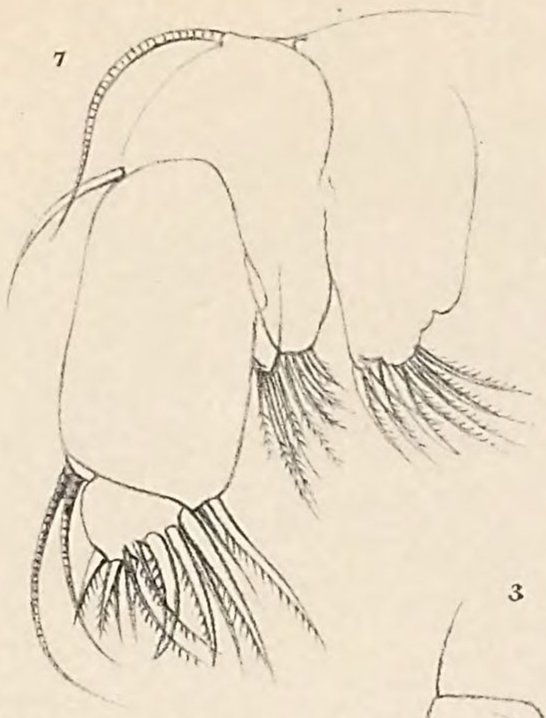
Figure

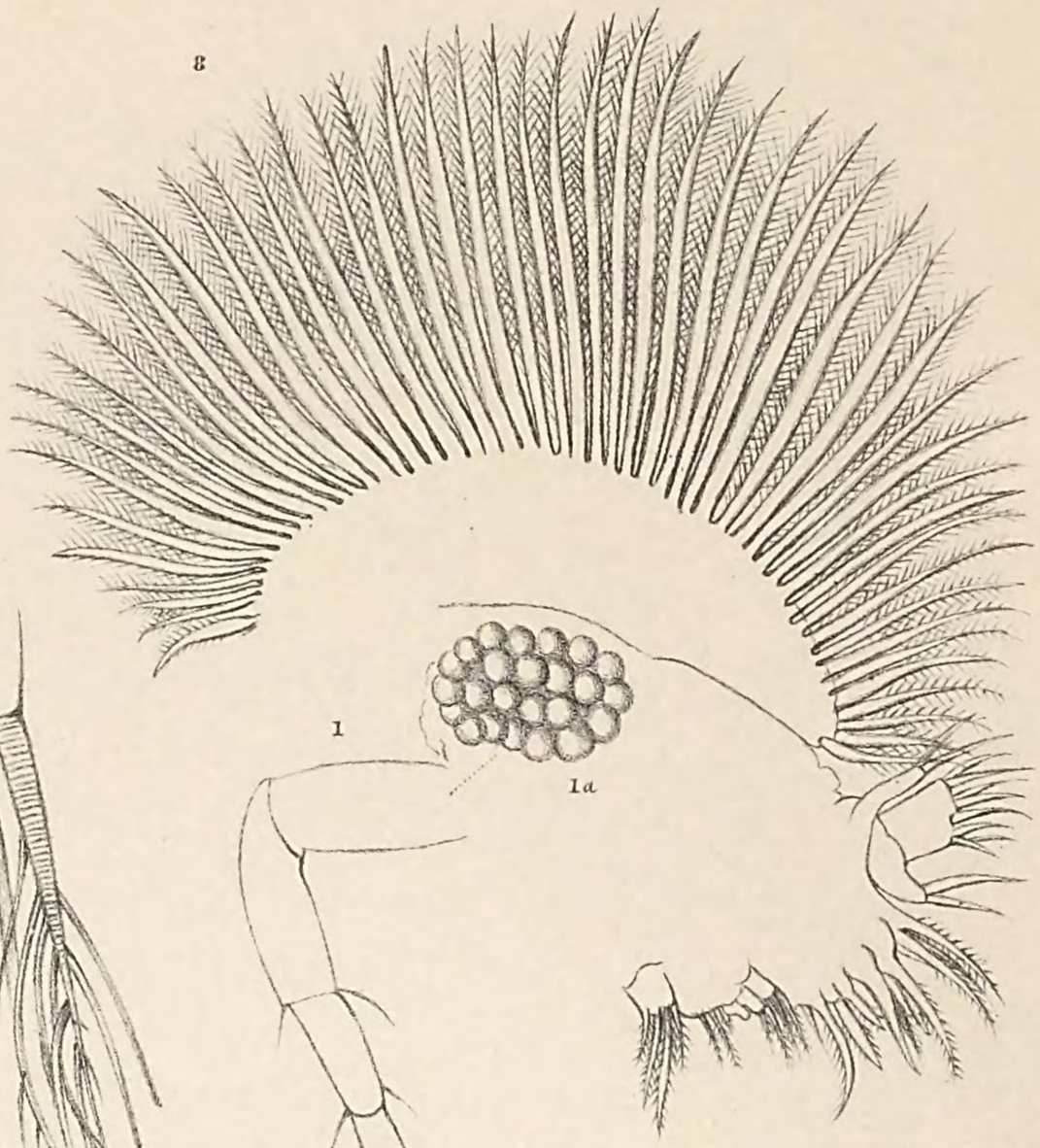
1. Antennule; (*a*) eye.
2. Portion of eye more highly magnified.
3. Terminal joints of antennule and portions of setæ more highly magnified.
4. Antenna.
5. Base of an antennal seta, with spine.
6. Mandibular foot.
7. Maxilla of first pair.
8. ,, second pair.
9. ,, third pair.
10. Extremity of vermiform limb.
11. Caudal lamina.

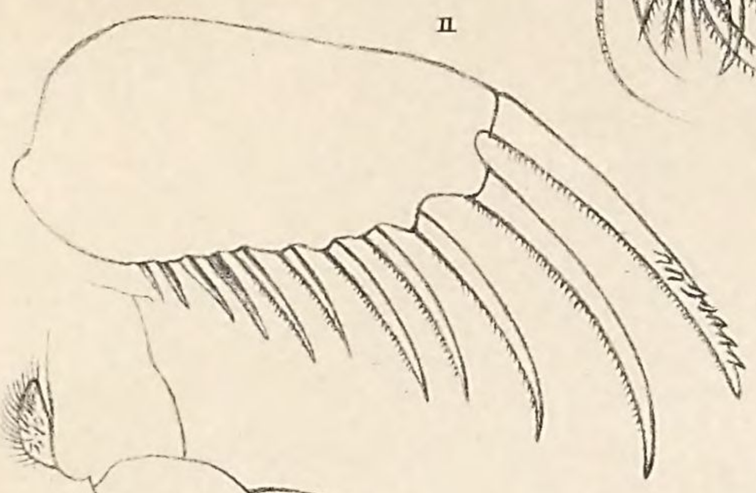
Polycope orbicularis, female.

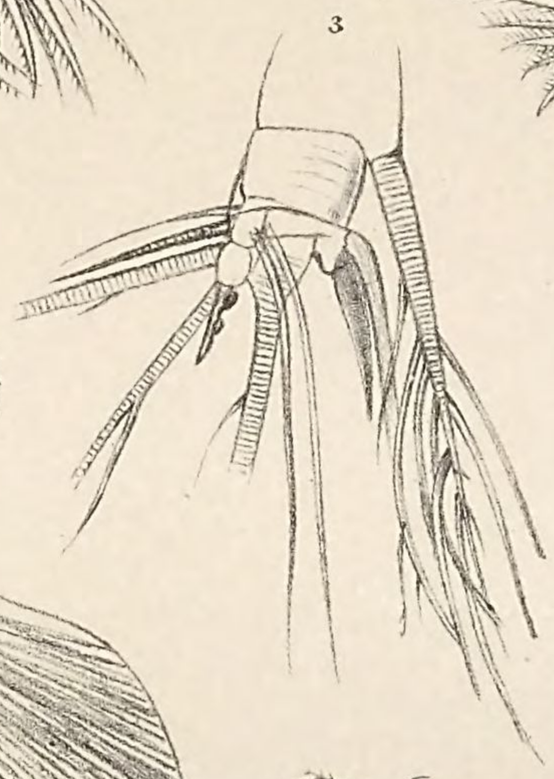
12. Animal seen from left side; left valve removed.
13. Mandible and palp.
14. Second maxilla, with branchial lamina.
15. Branchial lamina of the same, separated.
16. One of the caudal laminæ.


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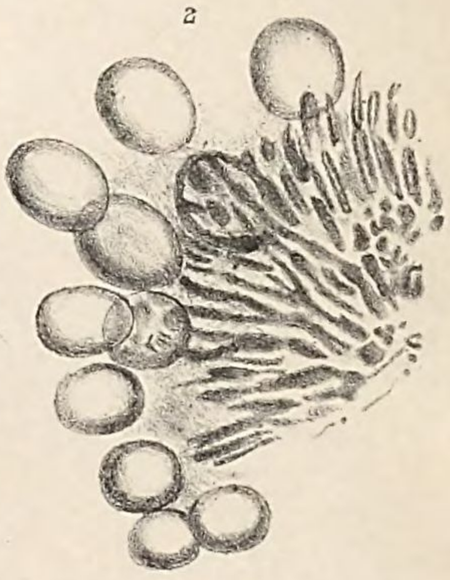

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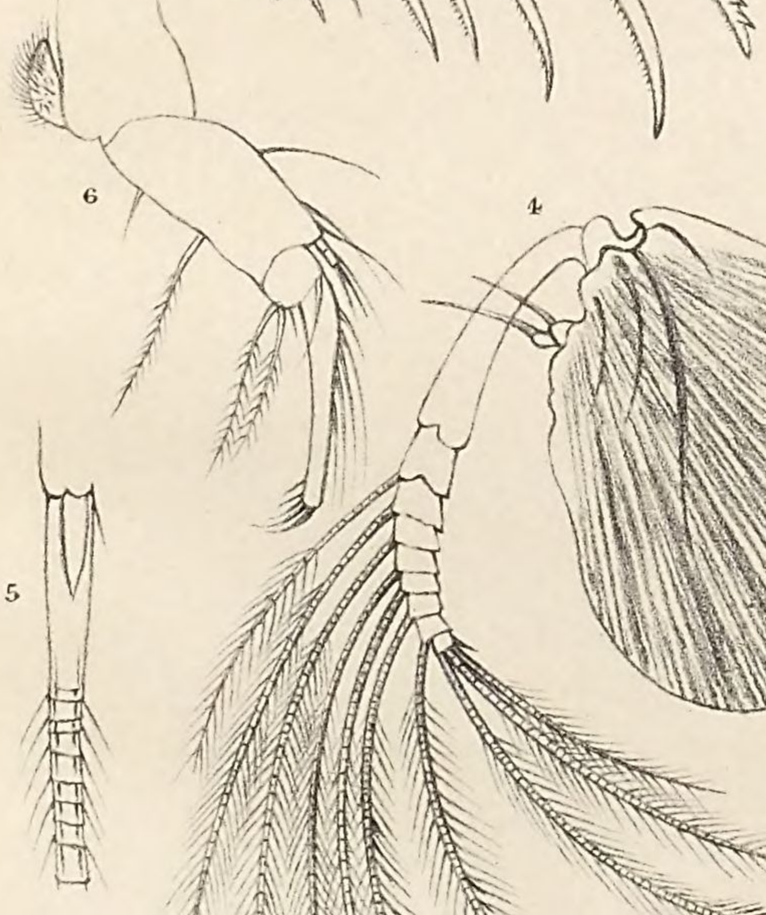

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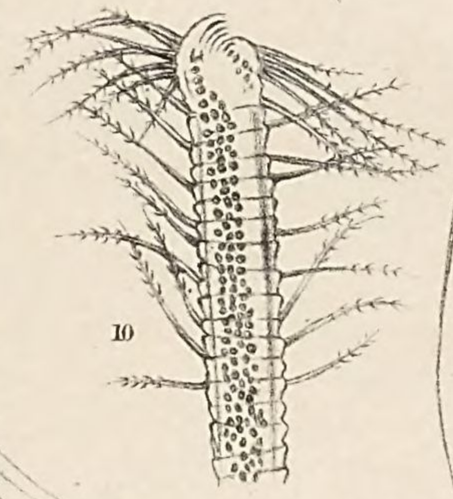
1a


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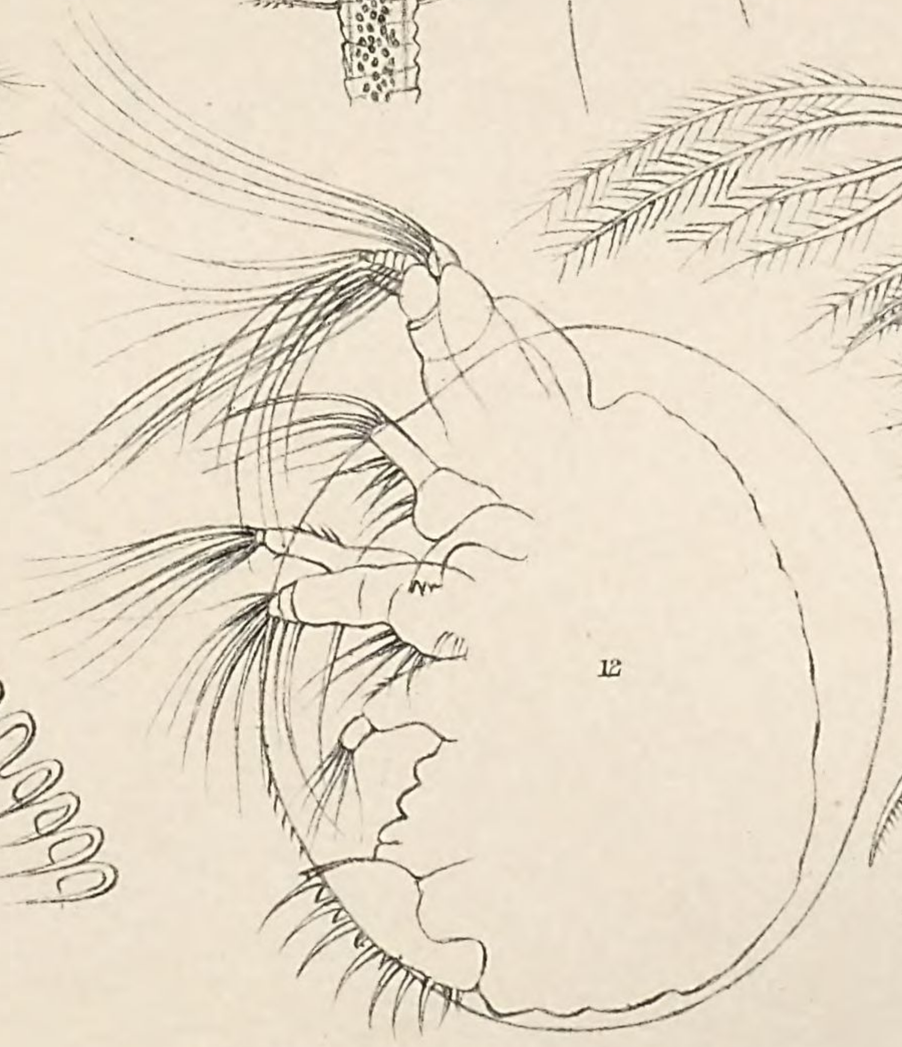

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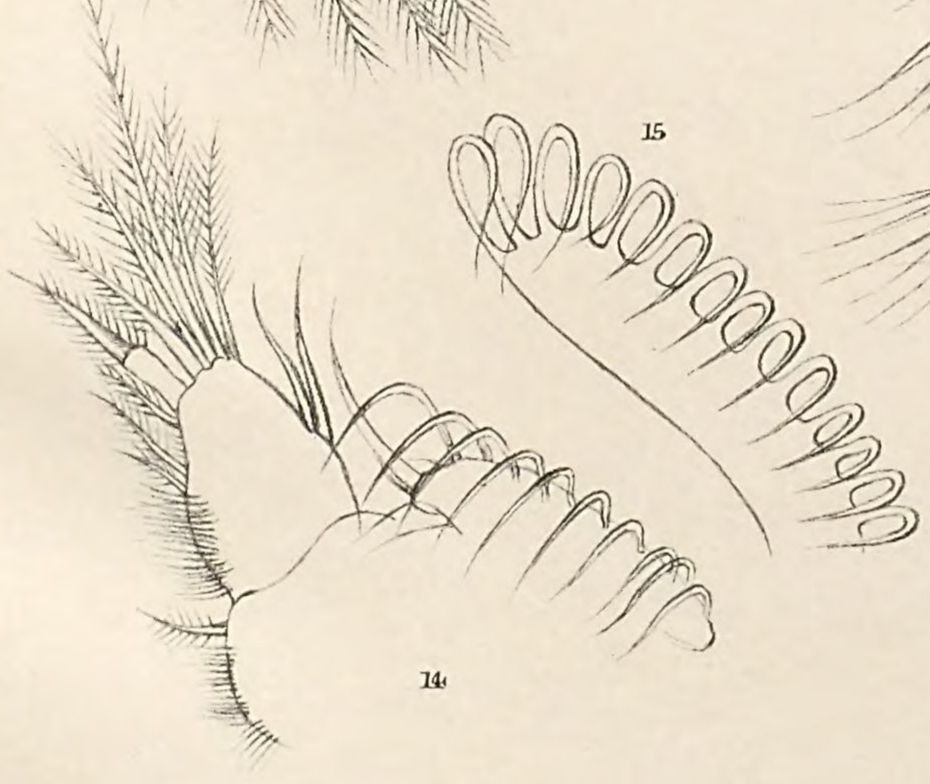
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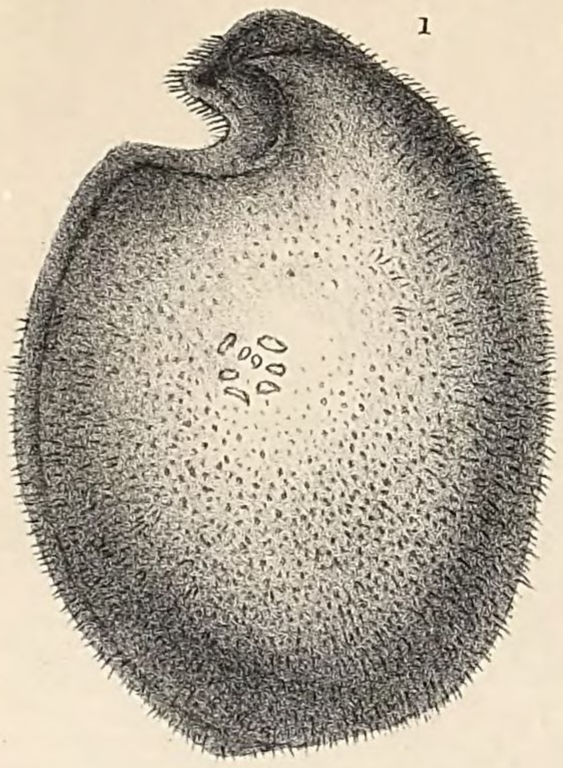

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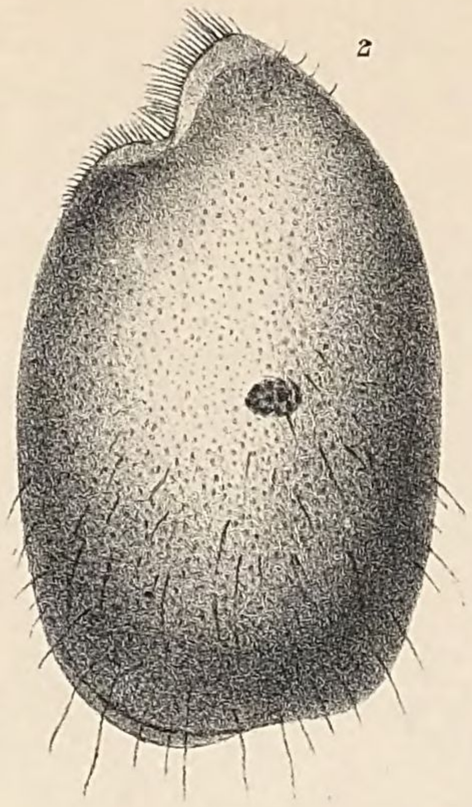
EXPLANATION OF PLATE LVI.

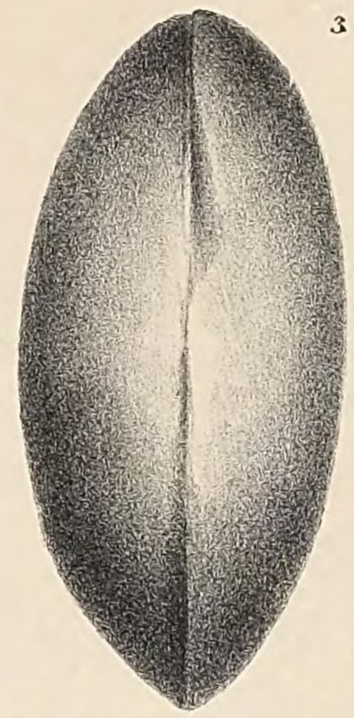
PLATE LVI.

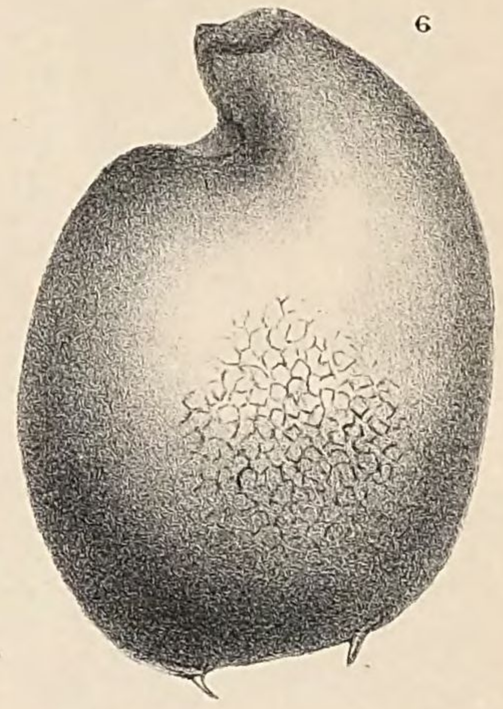
Figure

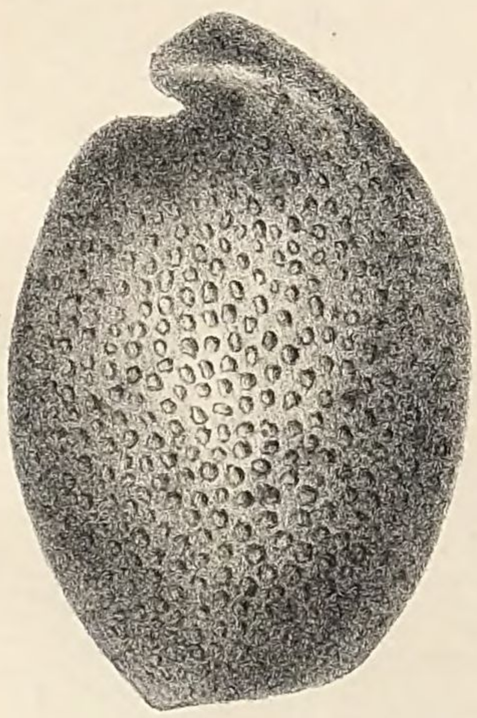
1. *Philomedes brenda*, female, seen from left side, ... × 25
2. ,, ,, male, ,, ,, ,, ,, ... × 25
3. ,, ,, ,, ,, ,, above, ... × 25
4. ,, *foveolata*, seen from left side, ... × 40
5. ,, ,, ,, ,, above, ... × 40
6. ,, *interpuncta*, female, seen from left side (Loch Long), . . × 50
7. ,, ,, ,, ,, ,, ,, ,, (Fosse de Cap Breton), . × 40
8. ,, ,, male, ,, ,, ,, ,, (Cumbrae), . . . × 40
9. ,, ,, ,, ,, ,, above, ,, . . . × 40
10. ,, *Folinii*, female, seen from left side, ... × 32
11. ,, ,, ,, ,, ,, above, ... × 32



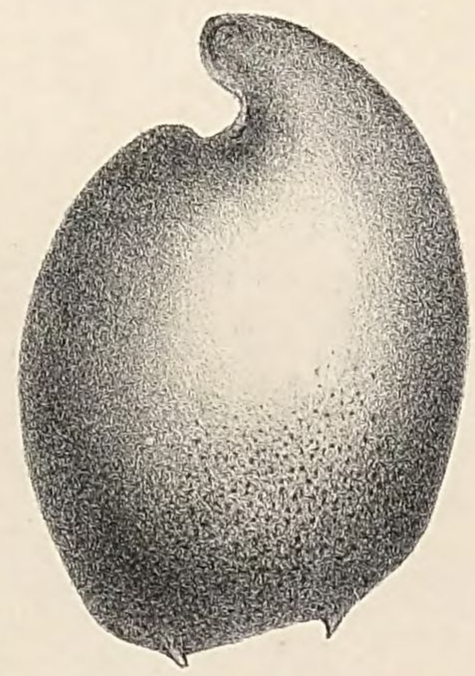


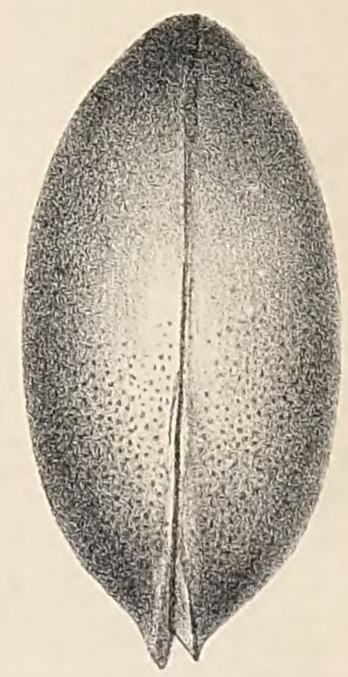


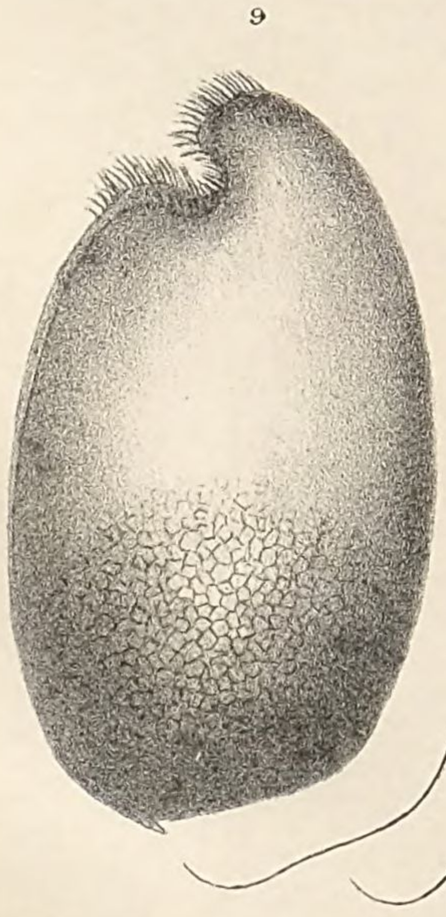


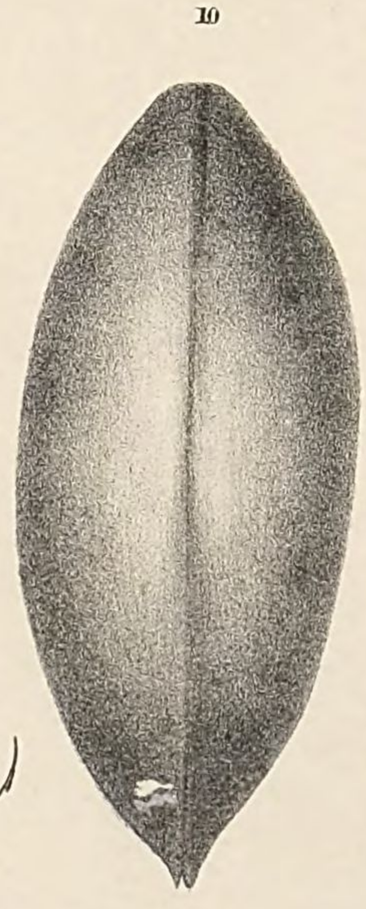


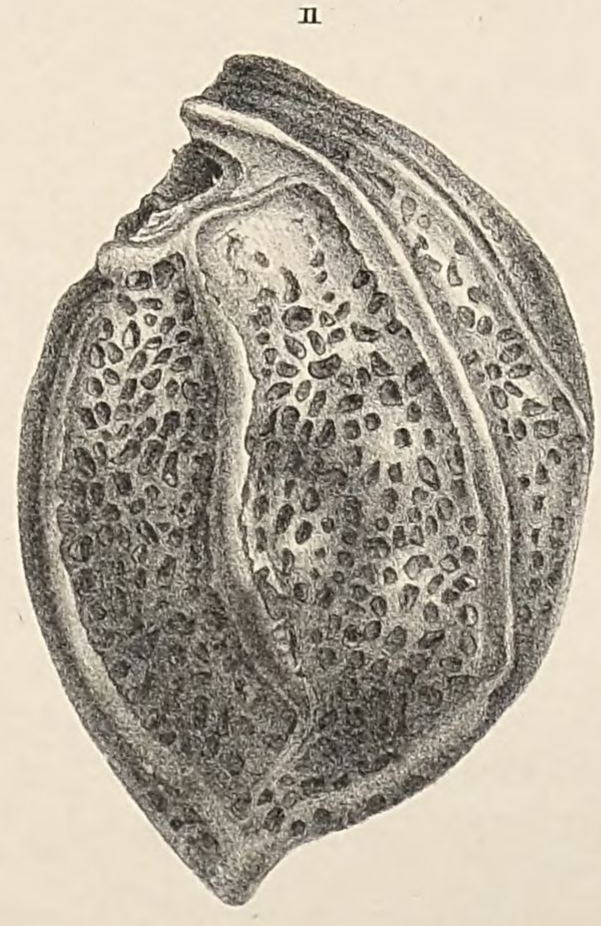


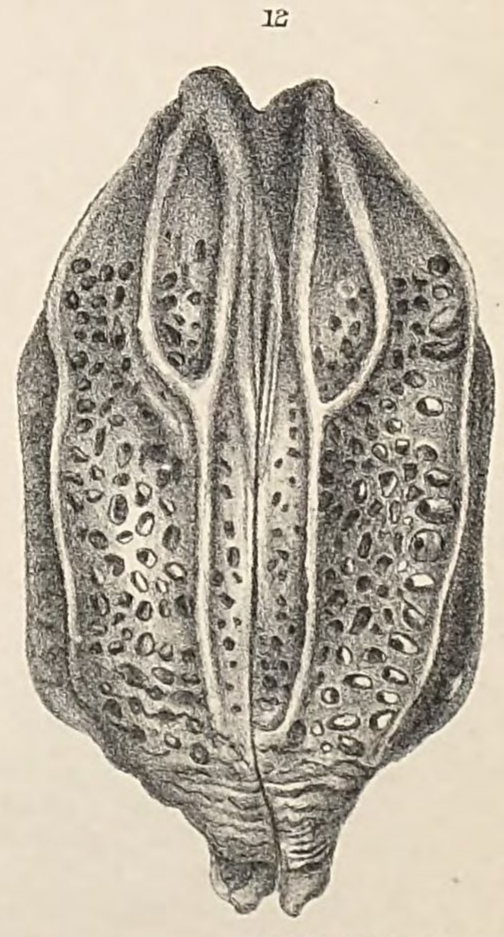












G. S. Brady, del.

Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LVII.

PLATE LVII.

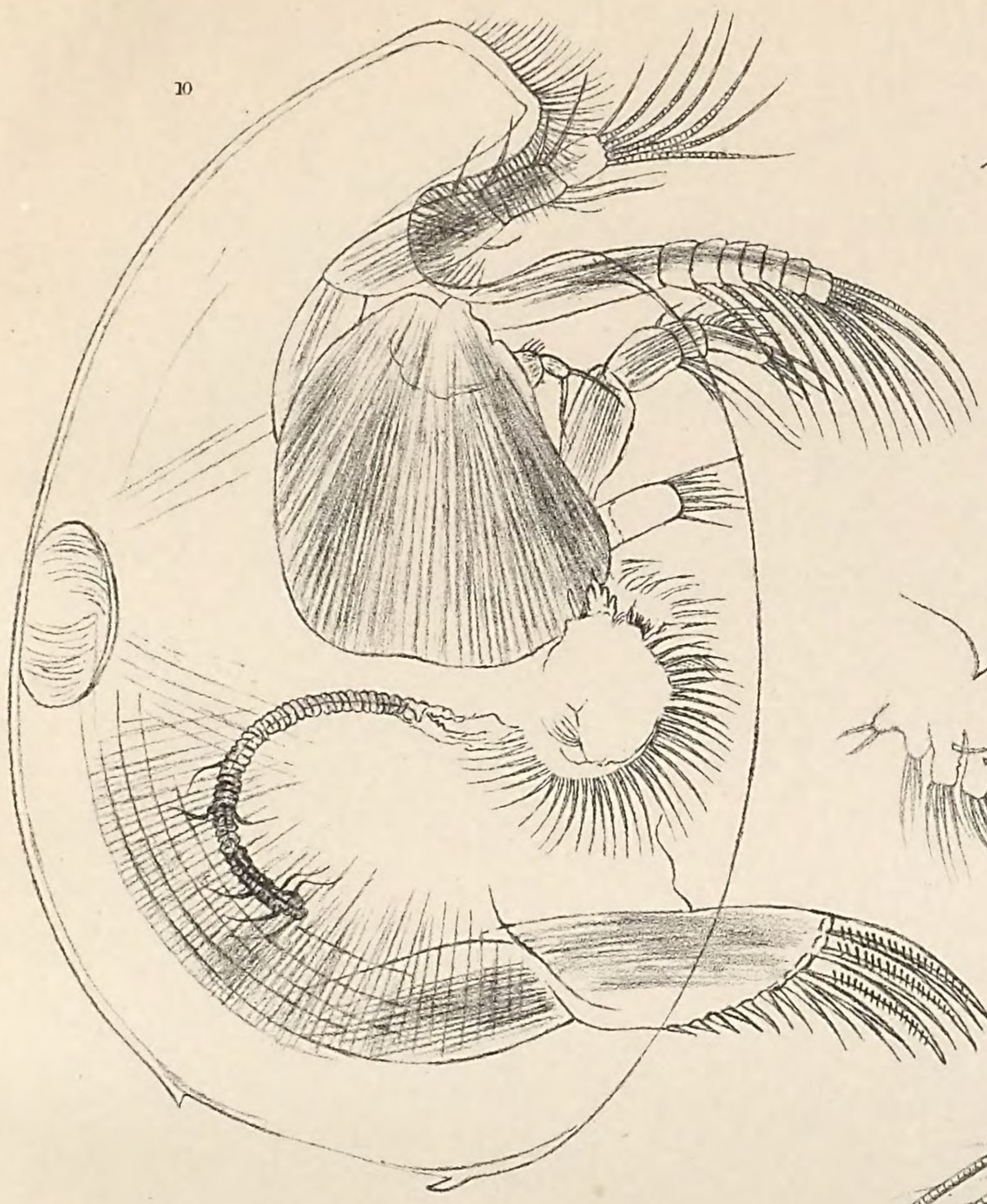
Philomedes interpuncta, male.

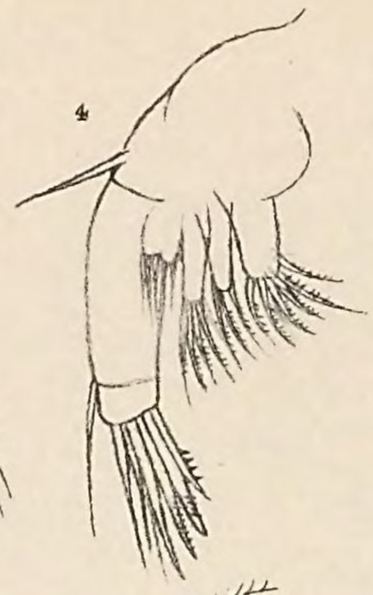
Figure

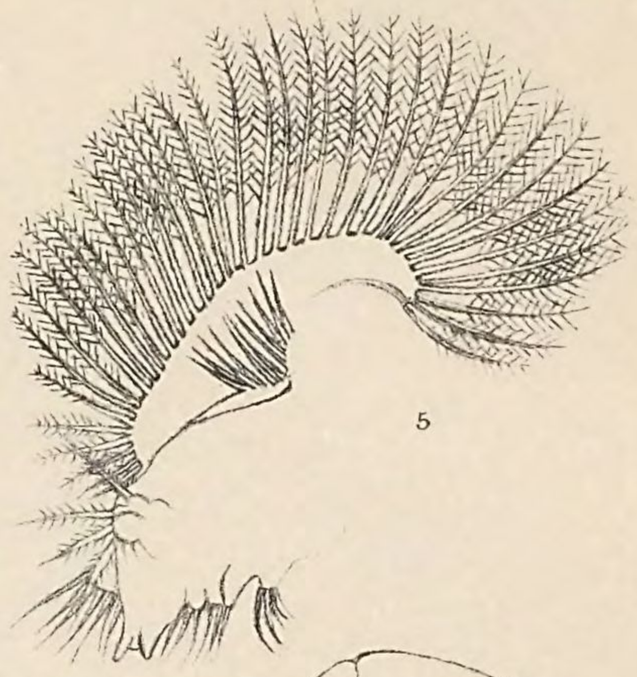
1. Antennule.
2. Antenna. 2 (*a*) Portion of first antennal seta.
3. Mandibular foot.
4. Maxilla of first pair.
5. ,, second pair
6. ,, third pair.
7. Vermiform limb. 7 (*a*) Spine of same more highly magnified.
8. Caudal lamina.
9. Eye.

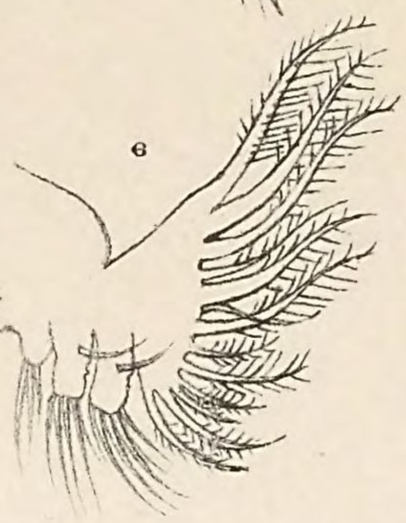
Philomedes interpuncta, female.

10. Animal seen from right side; right valve removed.
11. Antennule.
12. Antenna.
13. Mandibular foot.

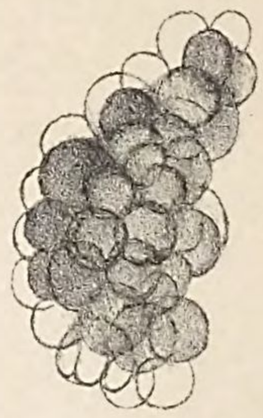

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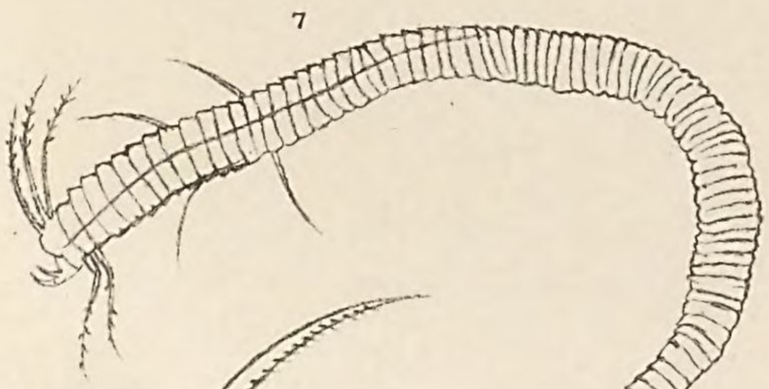

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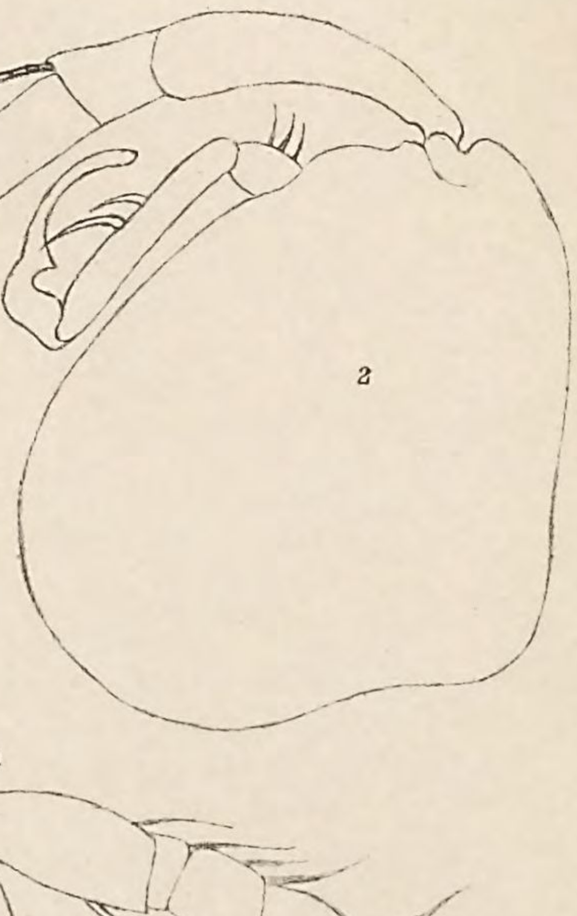

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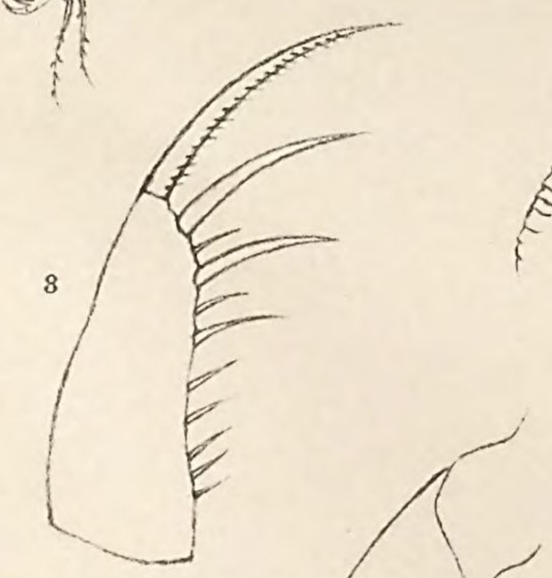

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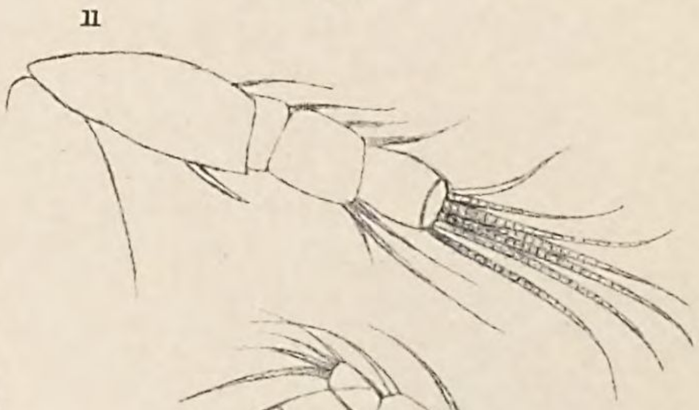

1

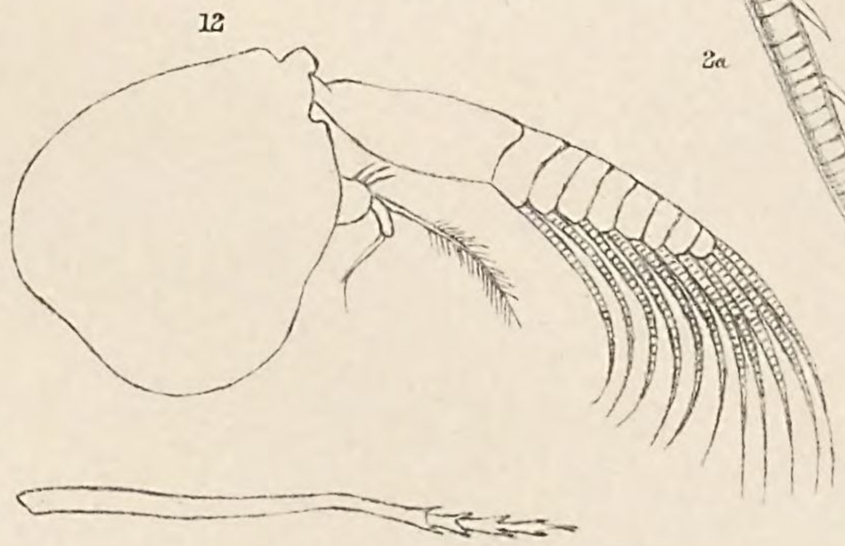

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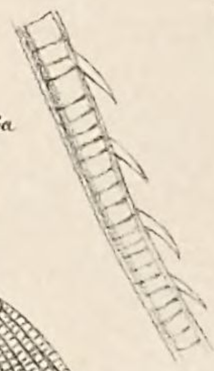

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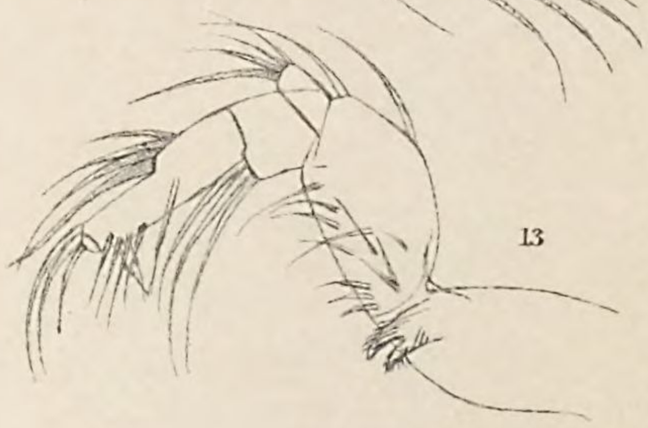

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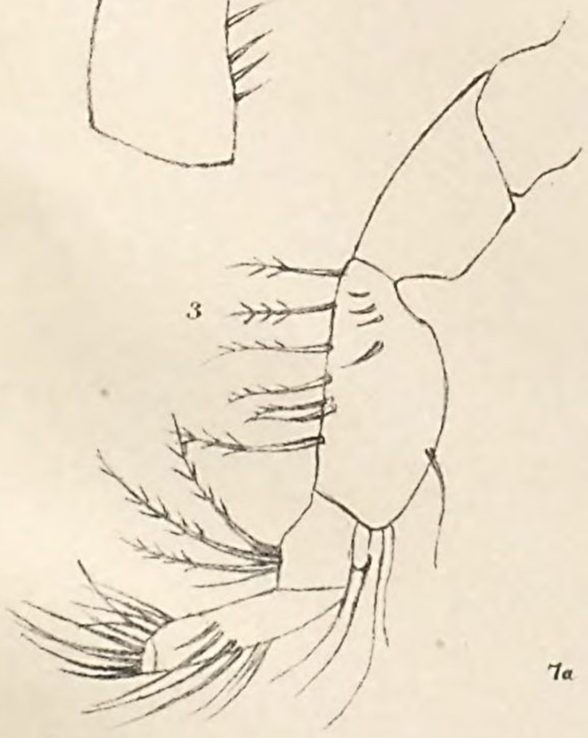

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G. S. Brady, del.

Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LVIII.

PLATE LVIII.

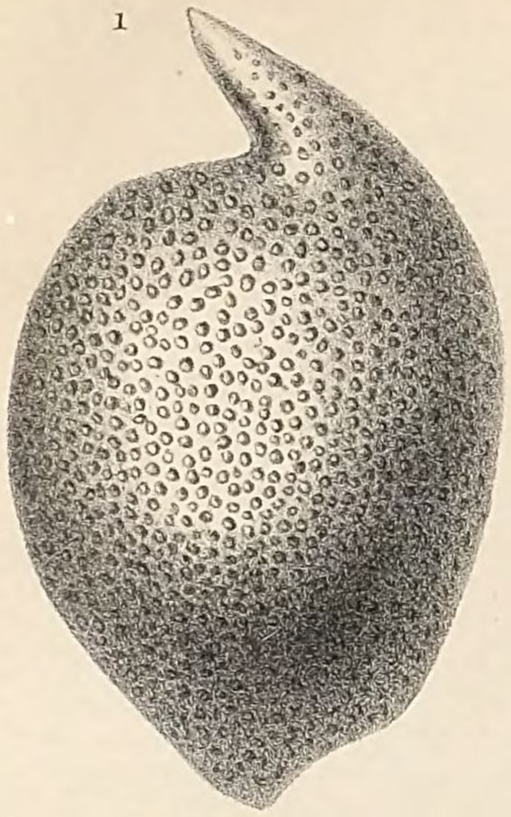
Tetragonidon ctenorhynchus, female.

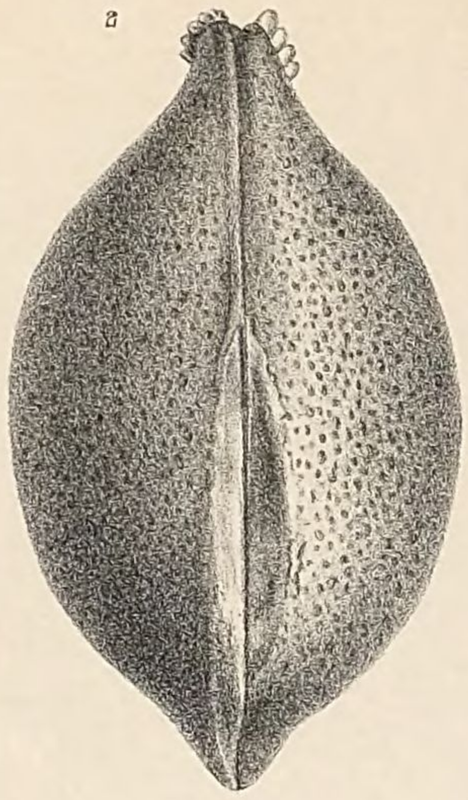
Figure

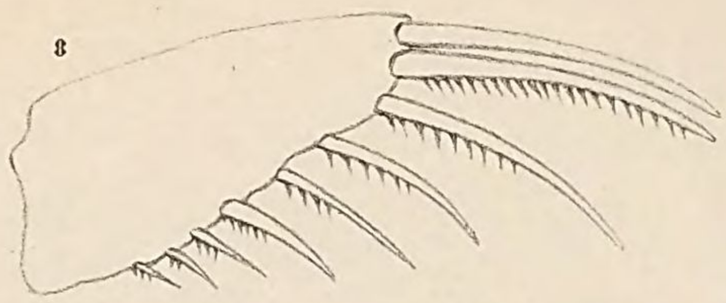
1. Shell, seen from left side, × 30.
2. ,, ,, ,, above, × 30.
3. Antennule.
4. Antenna.
5. Mandibular foot.
6. Outer tooth of second maxilla.
7. Apex of vermiform limb.
8. Caudal lamina.

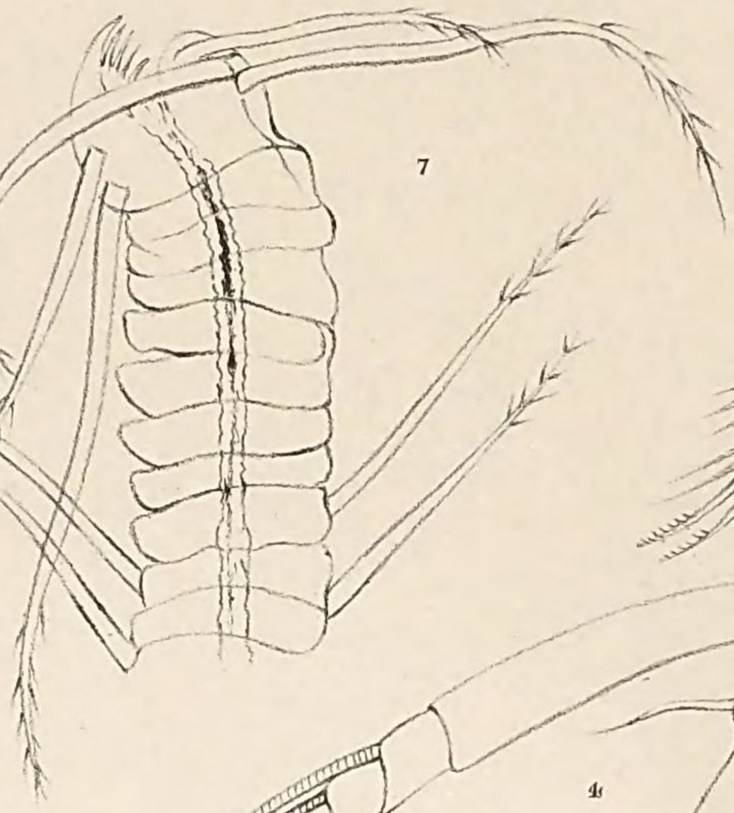
Rutiderma compressa, female.

9. Shell, seen from left side, × 40.
10. ,, ,, ,, above, × 40.
11. ,, ,, ,, front, × 40.
12. Antennule.
13. Antenna.
14. Mandibular foot. (*a*) One of the spines of the second joint more highly magnified.
15. Teeth and setæ of second maxilla.
16. Caudal lamina.


1


2

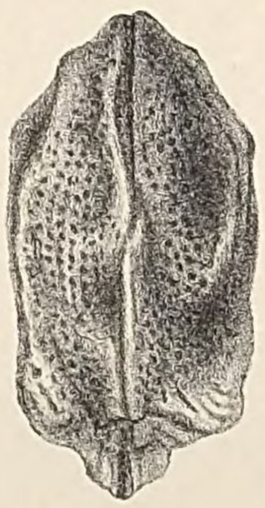

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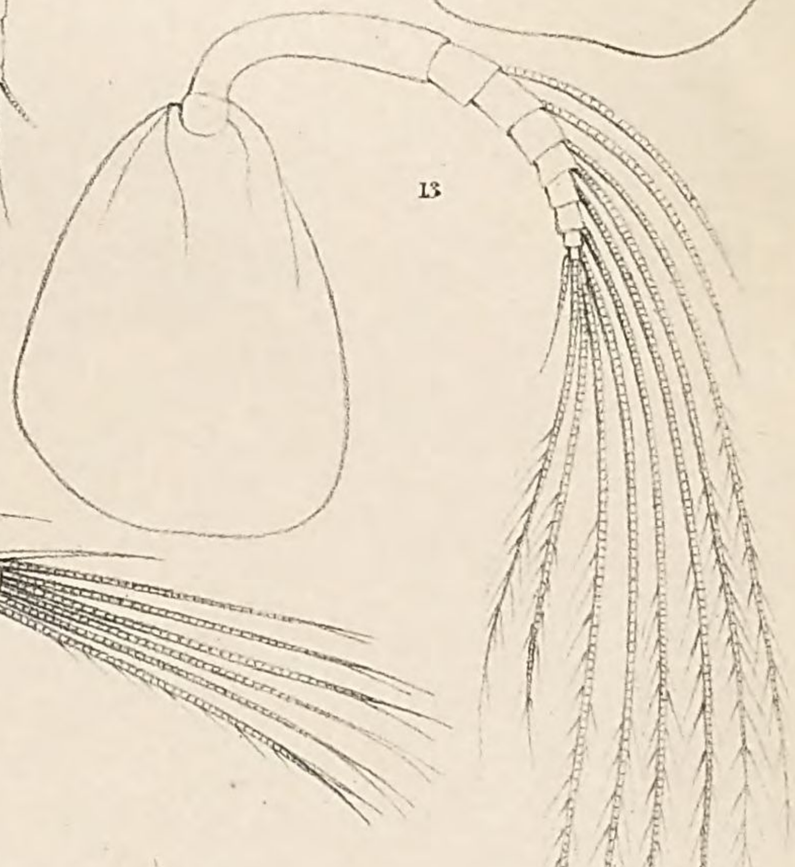

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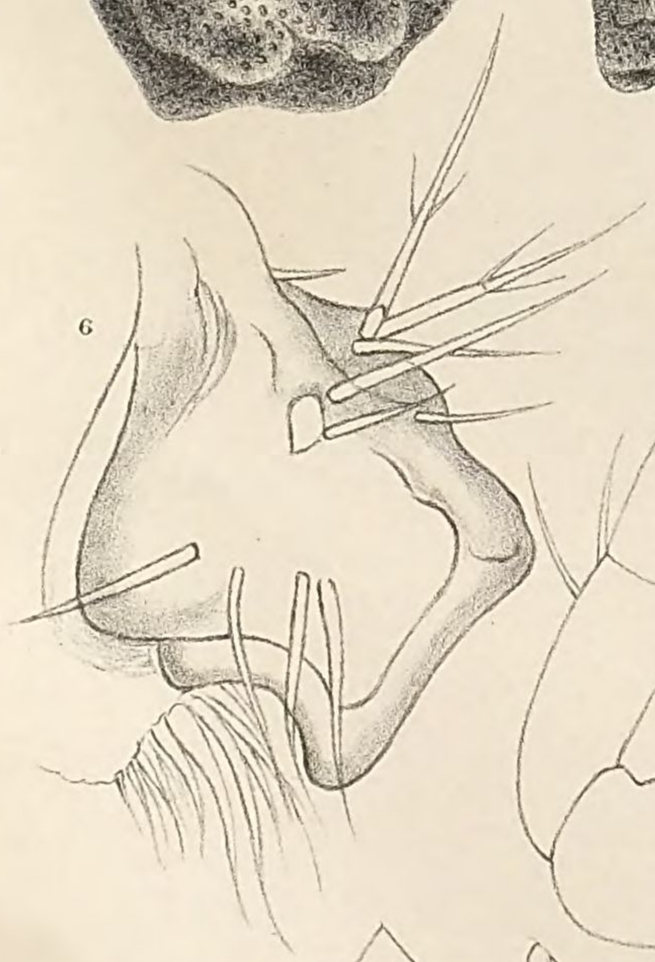

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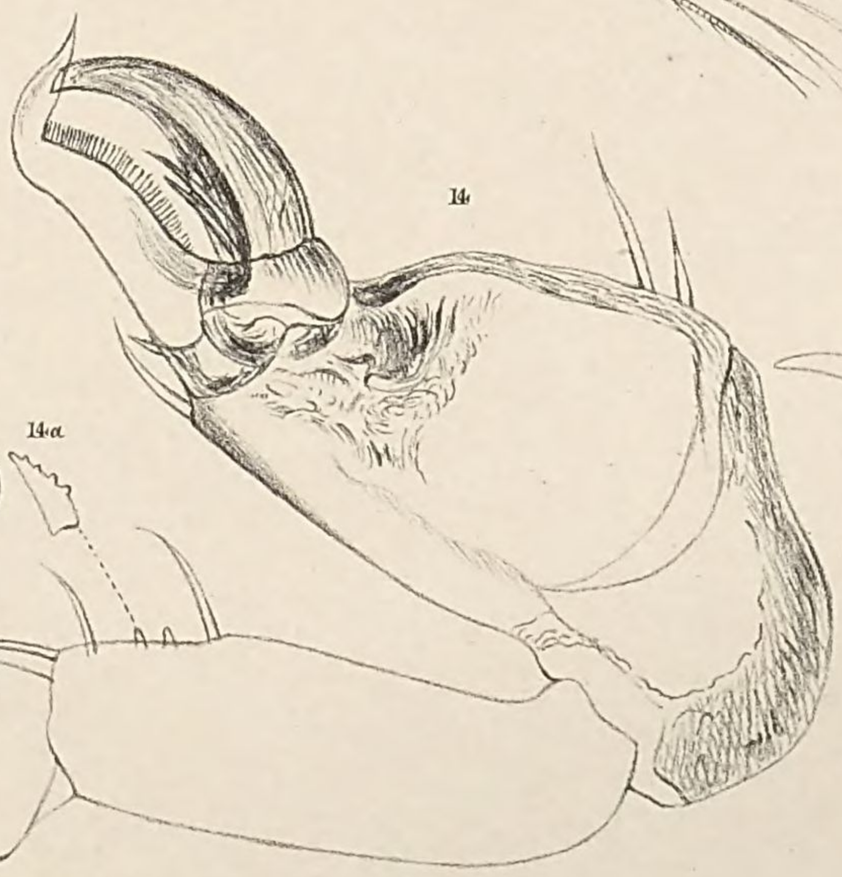
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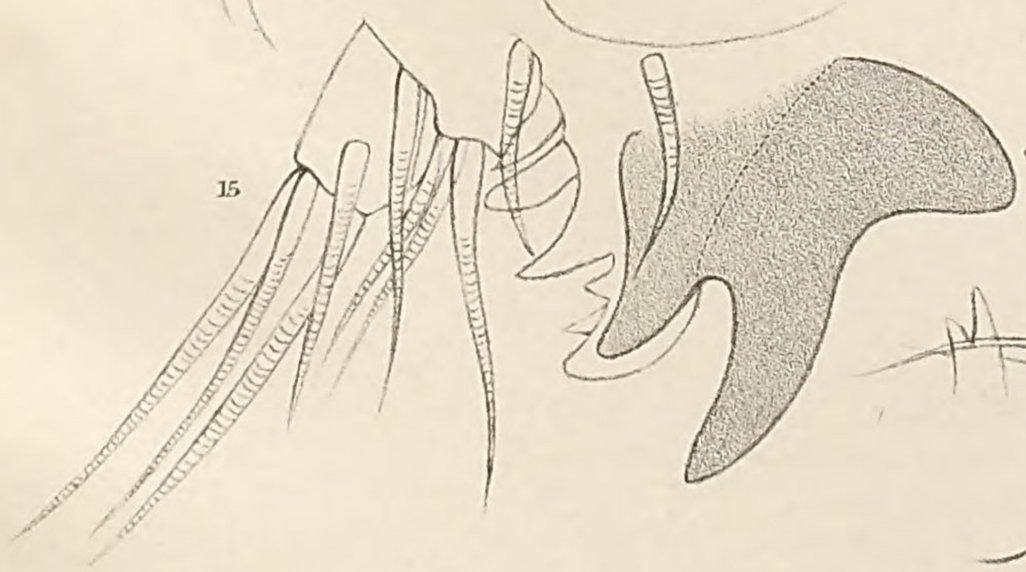

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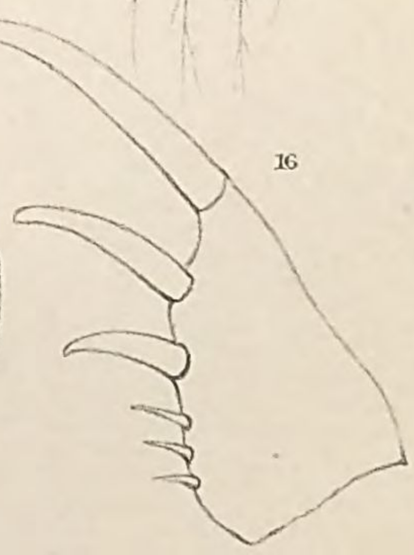

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14a


16

G. S. Brady, del.

Geo. West & Sons lith. et imp.



EXPLANATION OF PLATE LIX.

PLATE LIX.

Paramekodon inflatus, female.

Figure

1. Shell, seen from left side, × 30.
2. ,, ,, ,, above, × 30.
3. Antennule. (*a*) Portion of a sensory filament more highly magnified.
4. Secondary branch of antenna.
5. Mandible and palp.
6. Maxilla of first pair. (*a*) One of the shorter spines more highly magnified.
7. ,, second pair.
8. Teeth of the same more highly magnified.
9. Maxilla of third pair.
10. Caudal am

Streptoleberis rectirostris.

11. Shell, seen from left side, × 30.
12. ,, ,, ,, above, × 30
13. ,, ,, ,, behind × 30.

Tetragonodon erinaceus.

14. Shell, seen from left side, × 30.
15. ,, ,, ,, above, × 30.

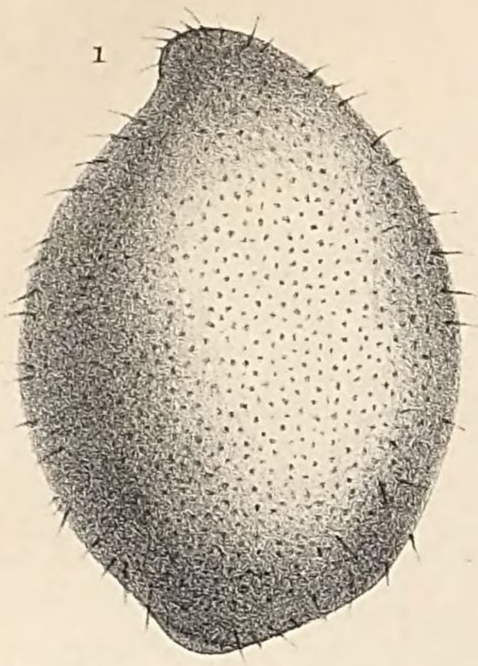
Streptoleberis favosa.

16. Shell, seen from left side, × 40.
17. ,, ,, ,, below, ,,
18. ,, ,, ,, front, ,,

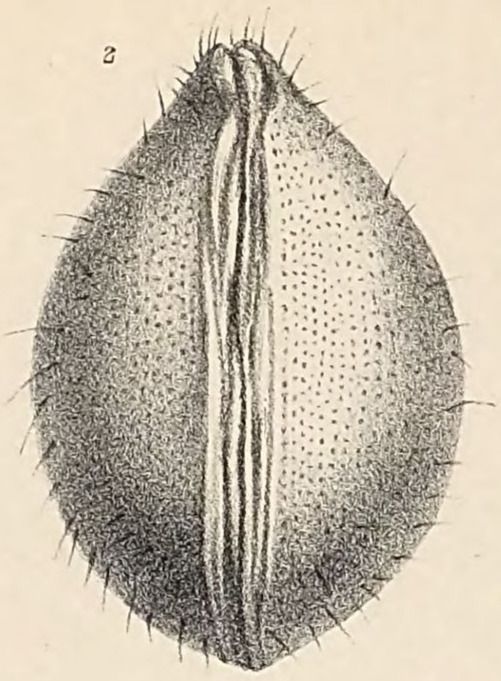
Asterope elliptica.

19. Antennule of female.
20. Mandibular foot of female.

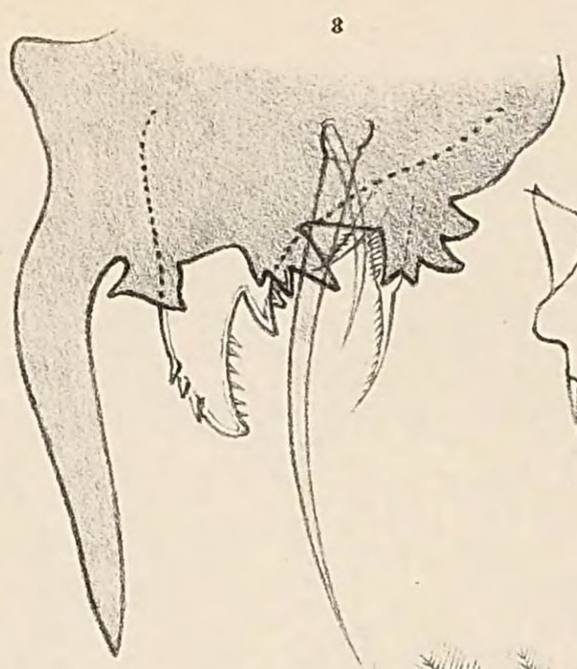
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2



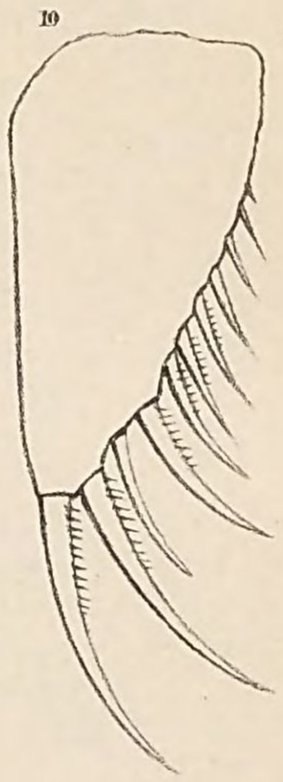
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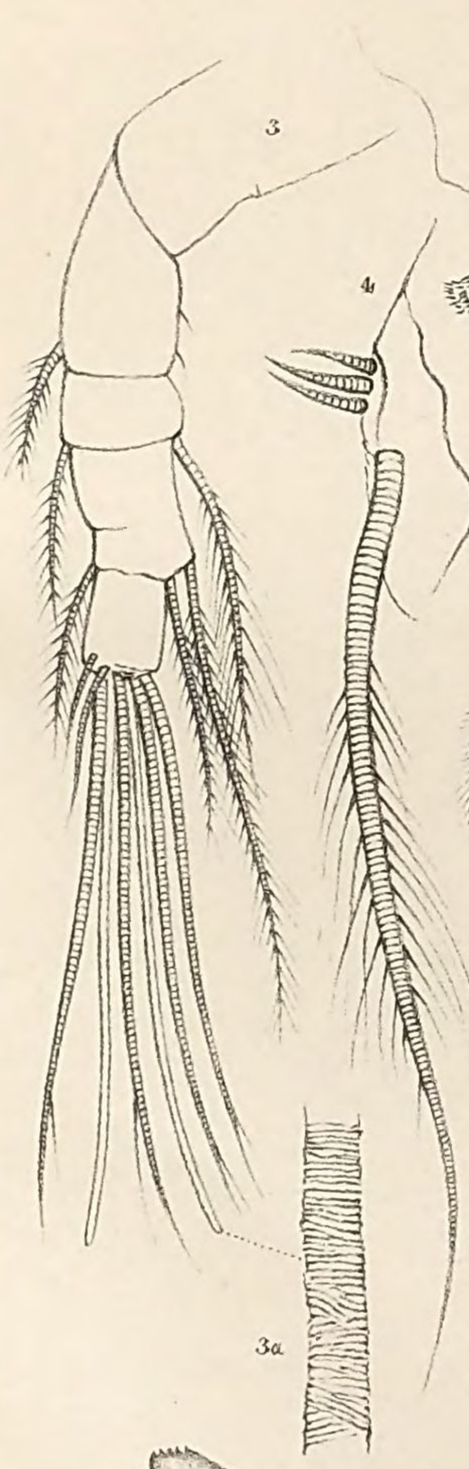
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10



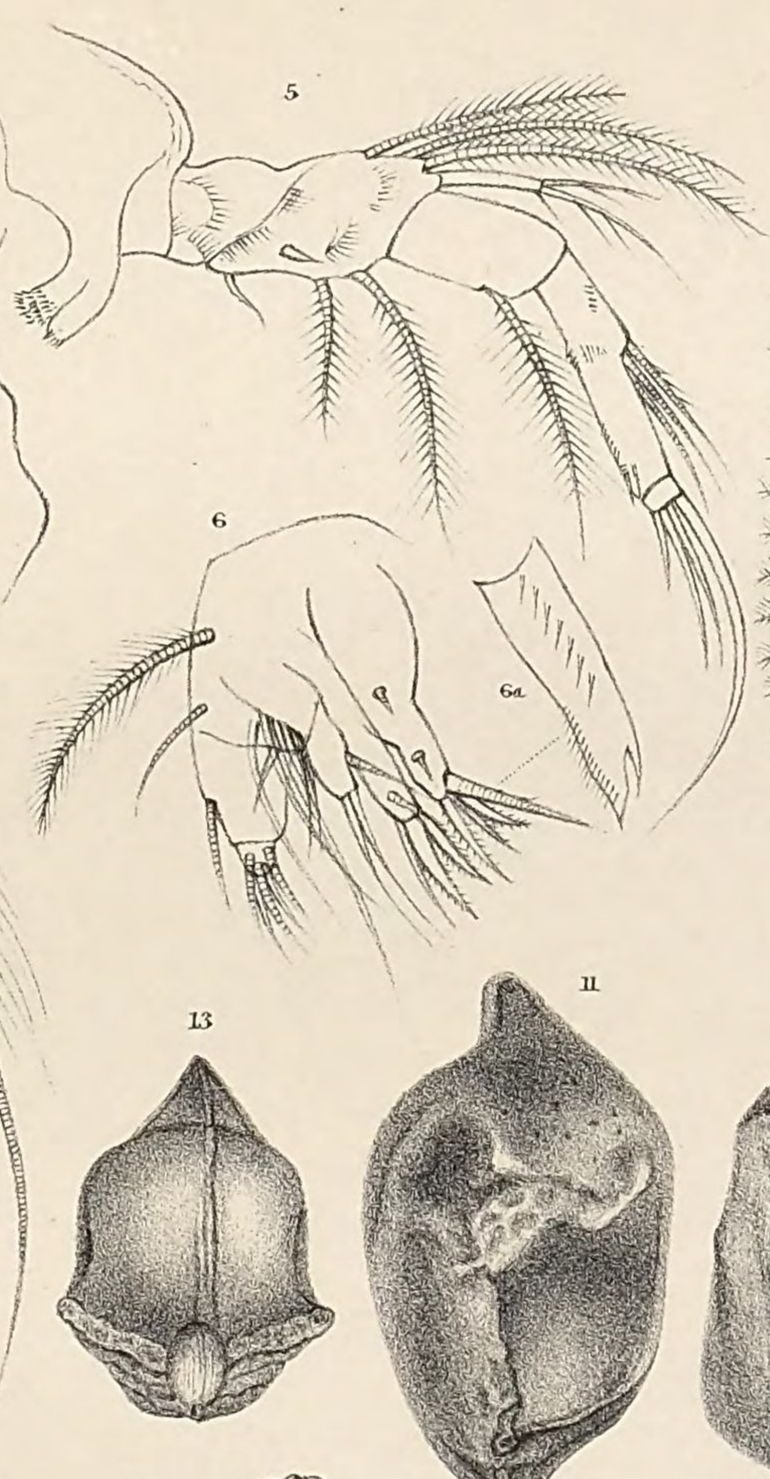
3



3a

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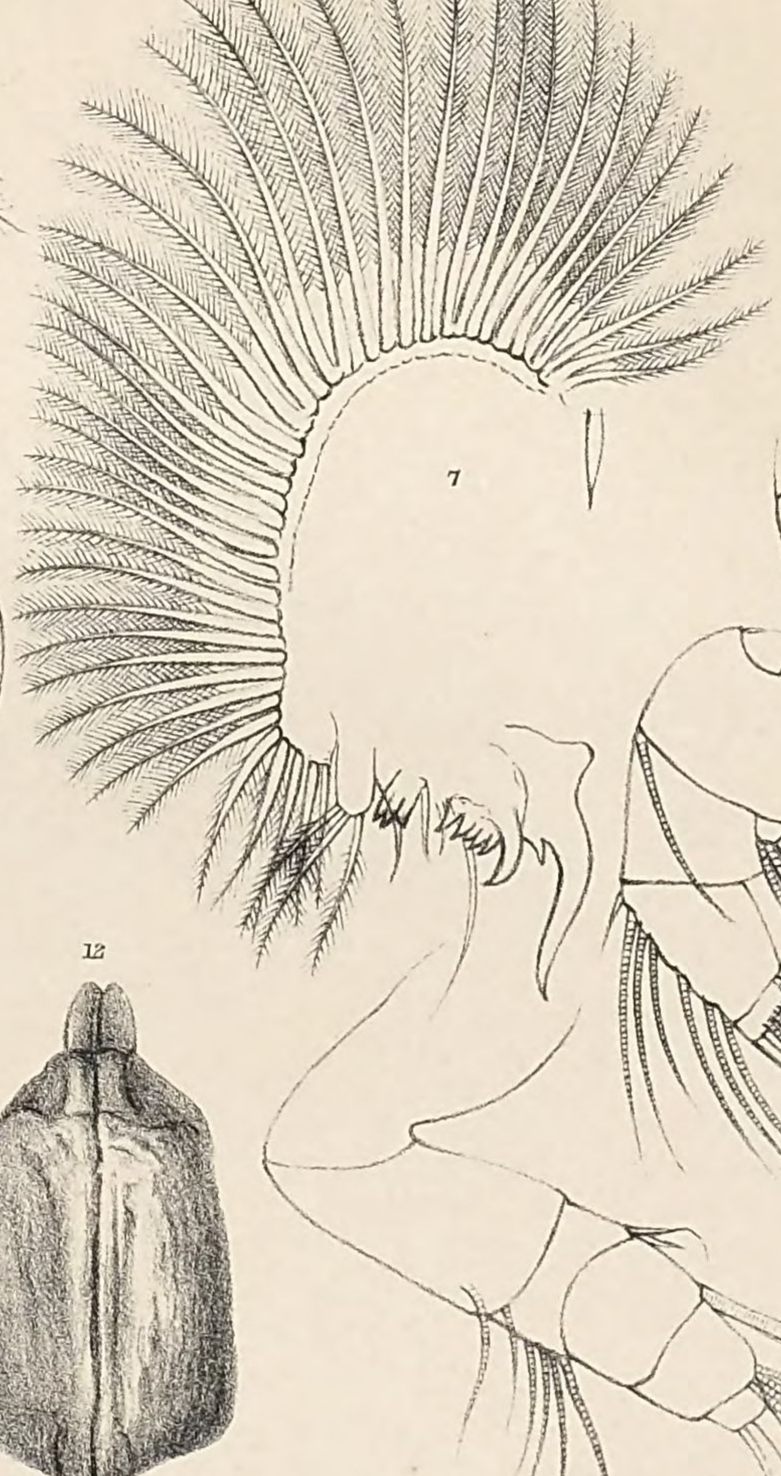
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19

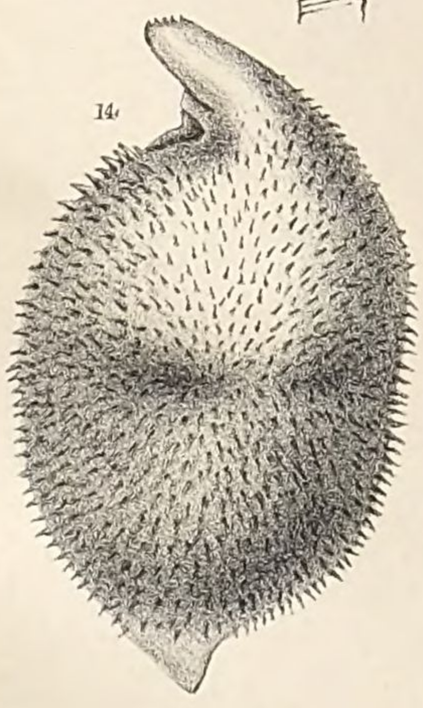


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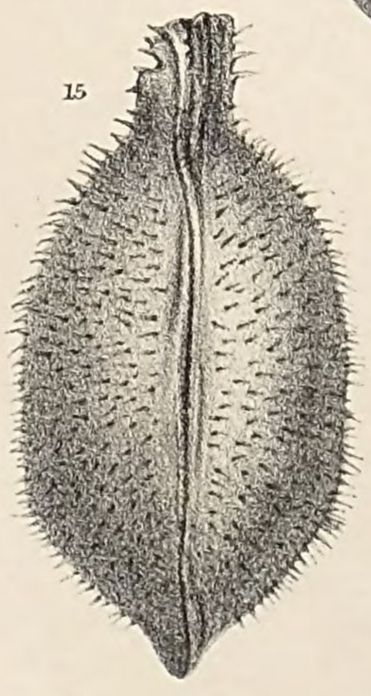
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13

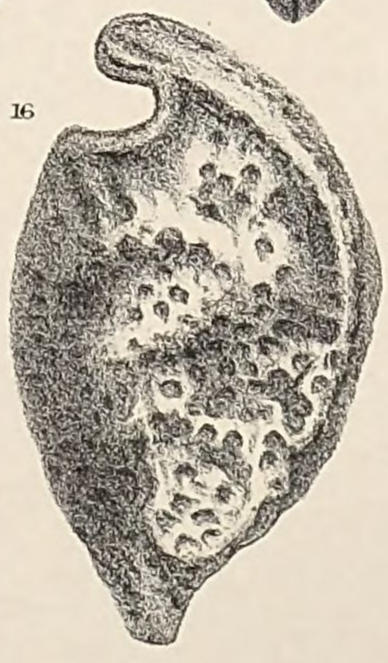
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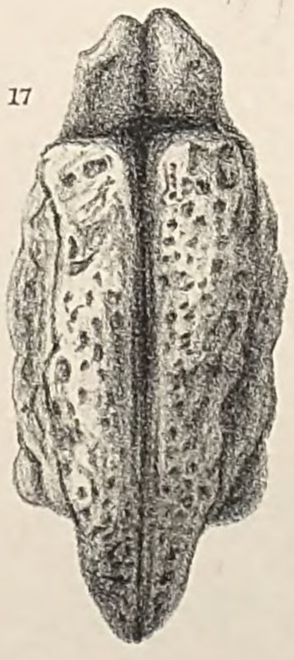
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EXPLANATION OF PLATE LX.

PLATE LX.

Sarsiella capsula, female.

Figure

1. Shell, seen from left side, ... × 40.
2. ,, ,, ,, above, ... × 40.
3. ,, ,, ,, below, ... × 40.
4. ,, ,, ,, behind, ... × 40.
18. First maxilla.

Sarsiella globulus, female.

5. Shell, seen from left side, ... × 30.
6. ,, ,, ,, below, ... × 30.
7. ,, ,, ,, front, ... × 30.
8. Antennule.
9. Appendicular branch of the antenna.
10. Mandibular foot.
11. First maxilla.
12. One of the spines of first maxilla.
13. Second maxilla.
14. Vermiform limb, apex.
15. ,, ,, one of the spines.
16. ,, ,, chitinous bands.
17. Caudal lamina.

Cypridina norvegica, male.

19. Terminal joints of antennule with setæ.
20. Spine of antennule, with suctorial disc.
21. One of the disc-bearing setæ of antennule.

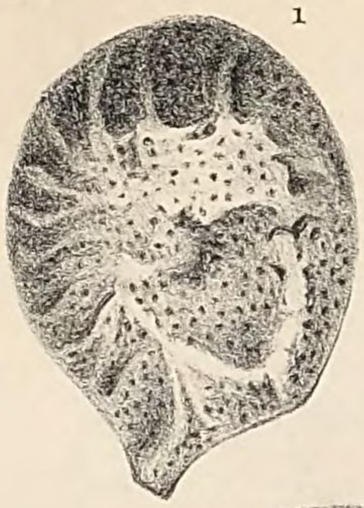
Conchœcia spinirostris, male.

22. Armature of the principal seta of antennule.

Conchœcia elegans, male.

23. Armature of the principal seta of antennule.

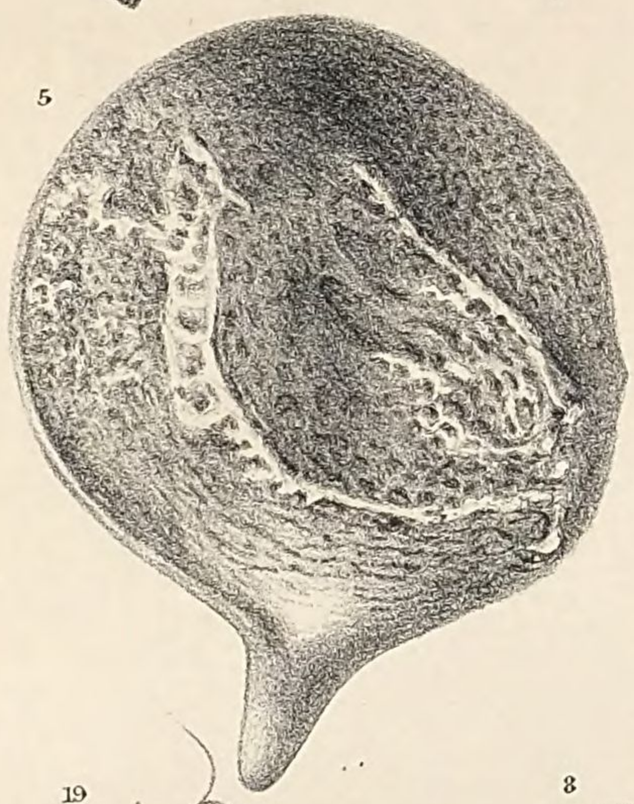
Trans. R. Dub. S., N.S., Vol. V.

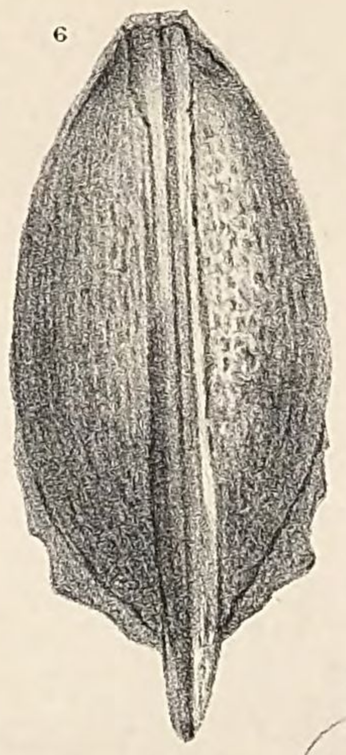

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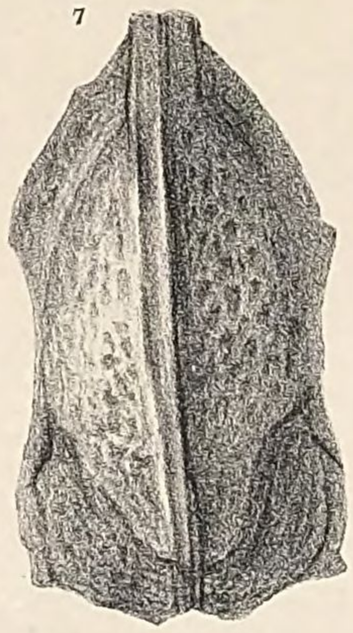

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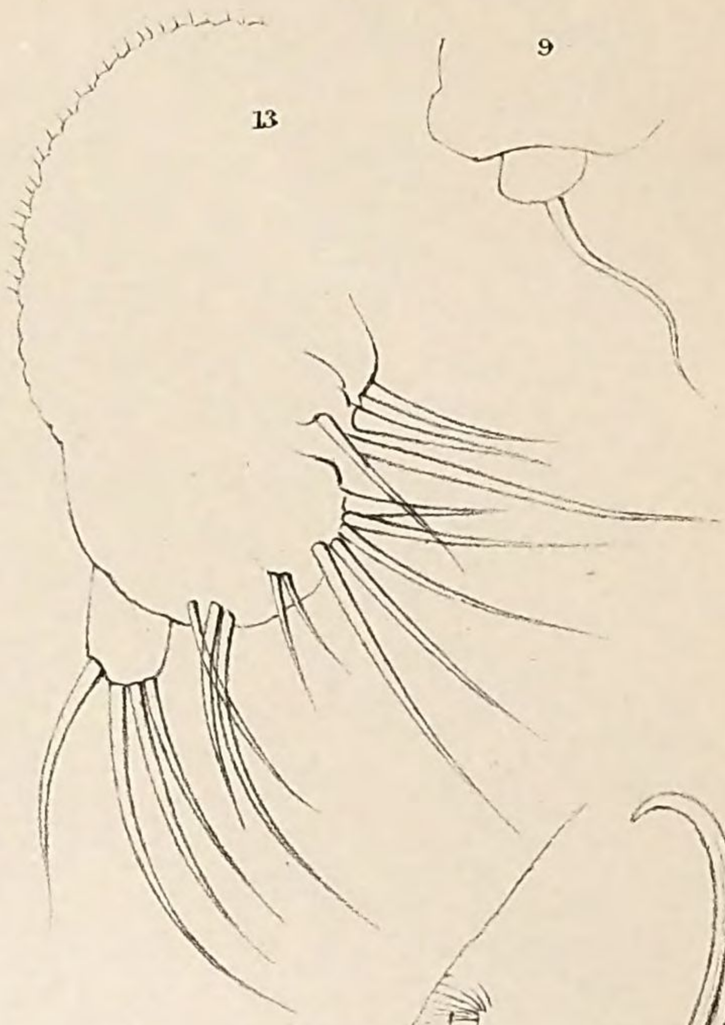

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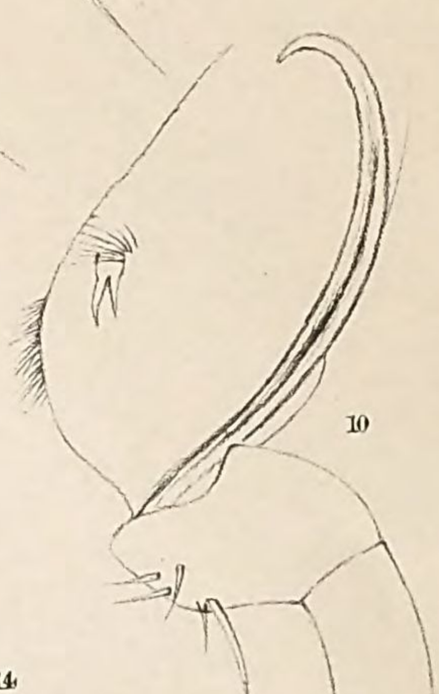

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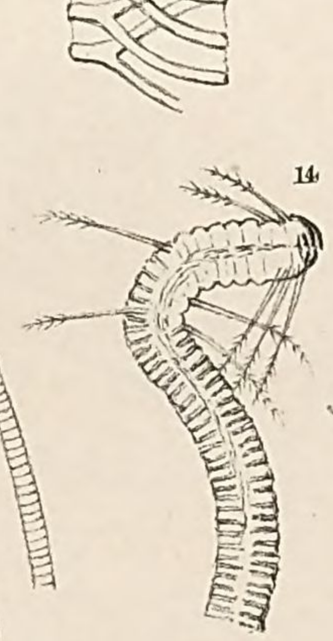

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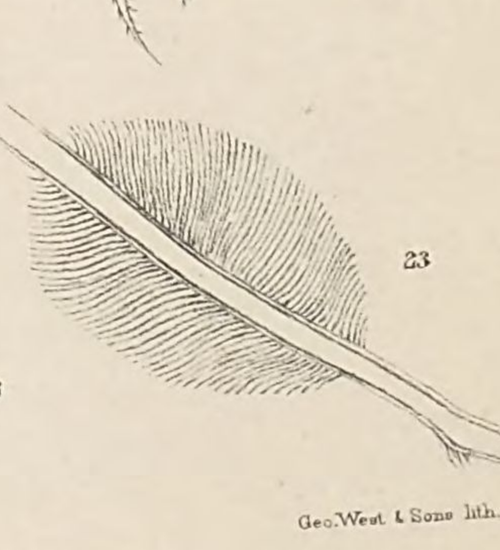
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Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LXI.

PLATE LXI.

Conchœcia maxima.

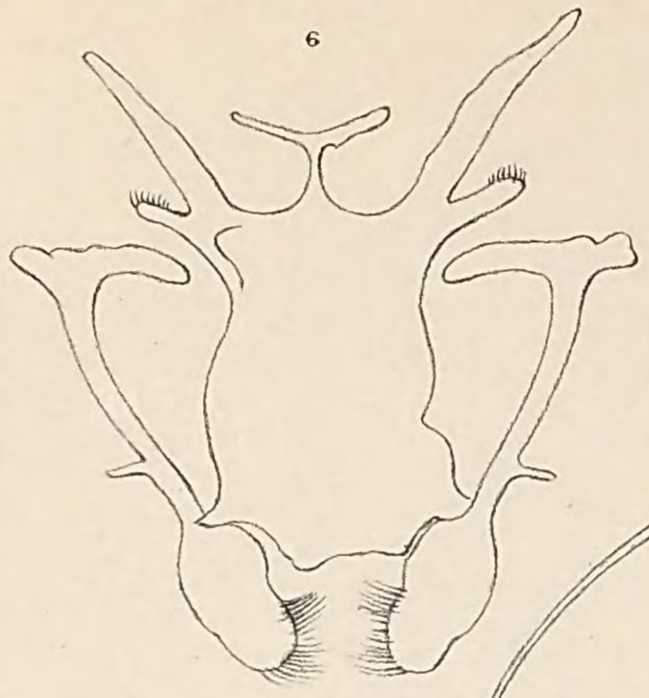
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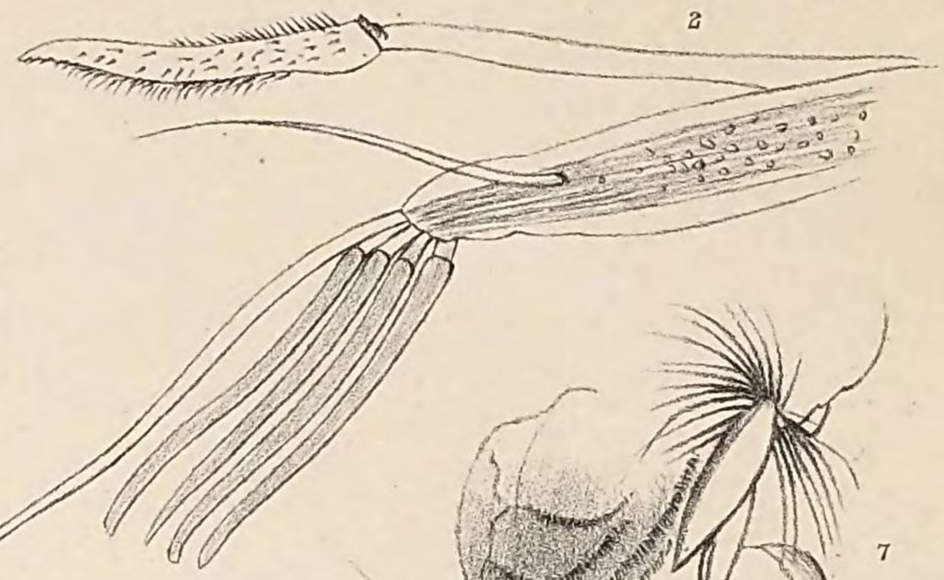
1. Female, seen from left side, left valve removed, × 23. (*a*) Teeth of postero-dorsal angle of shell of male.
2. Antennule and frontal tentacle of female.
3. End of frontal tentacle of male.
4. Portion of seta of antennule of male, showing marginal spines.
5. Secondary branch of antenna of male.
6. Labrum, labium, &c.
7. End of mandible of male.
8. Reticulation of shell.

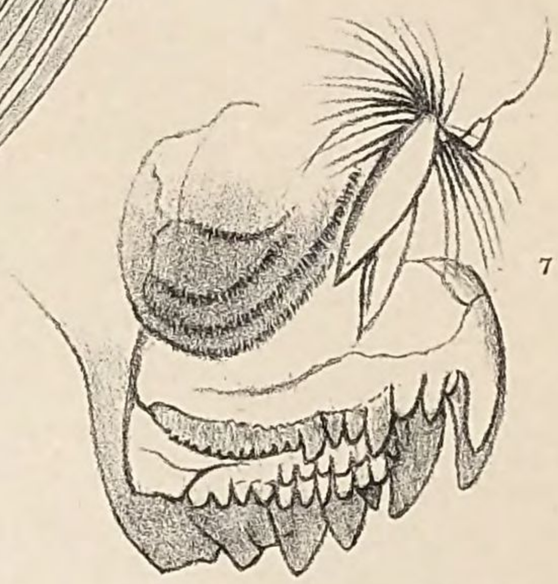
Conchœcia borcalis.

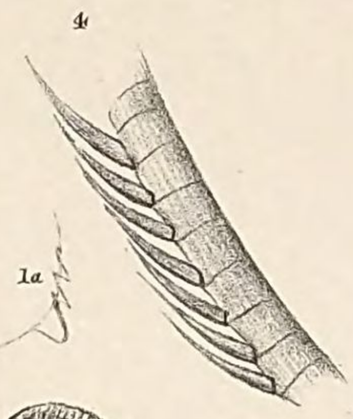
9. Female, seen from right side, × 34.
10. ,, in outline, seen from above.
11. Teeth of postero-dorsal angle.
12. Antennule of female.
13. ,, ,, male.
14. Spinous portion of anterior antennular seta of male.
15. Frontal tentacle of female.
16. Secondary branch of antenna, female.
17. Caudal lamina and ovaries.
18. Copulatory organ of male.
19. Shell structure.

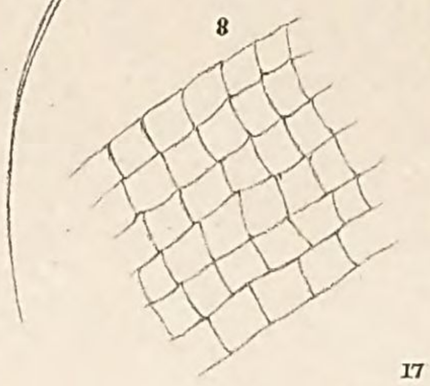

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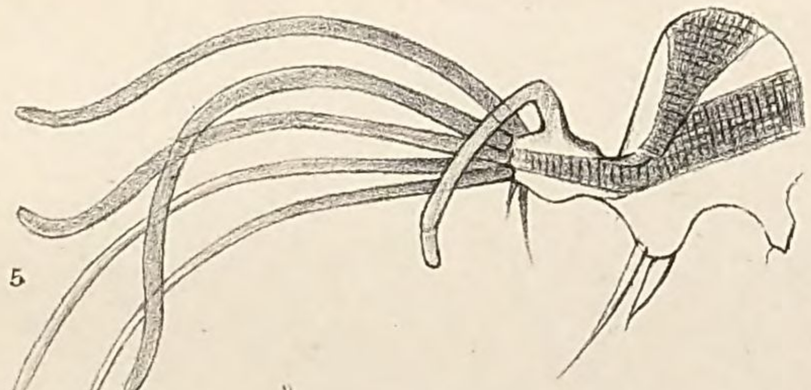

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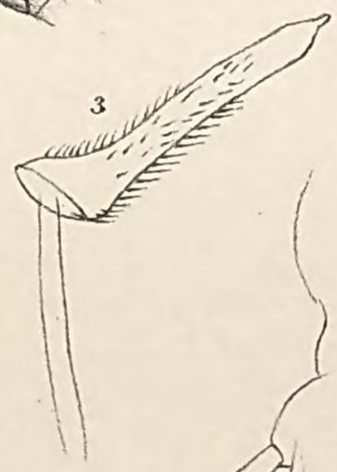

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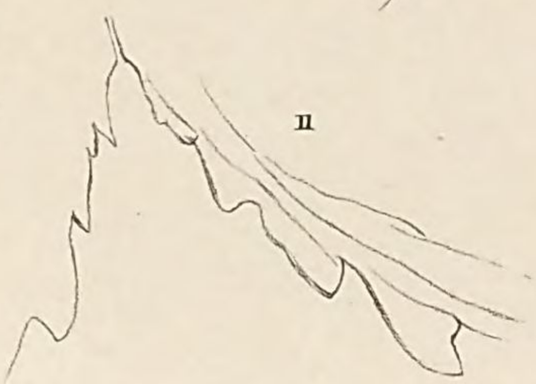

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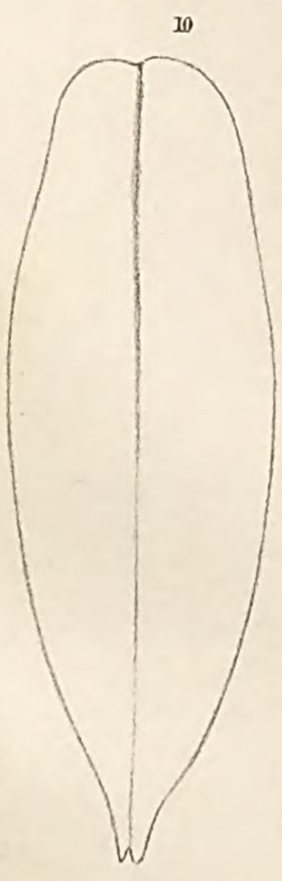

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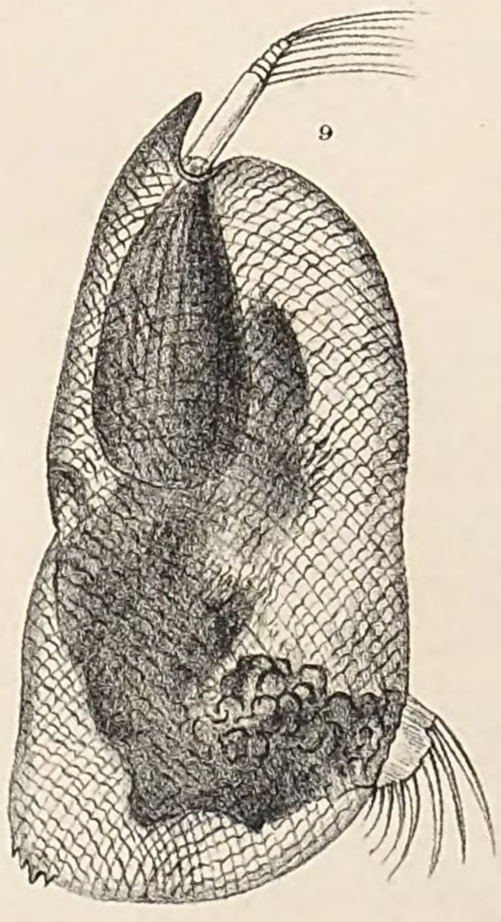

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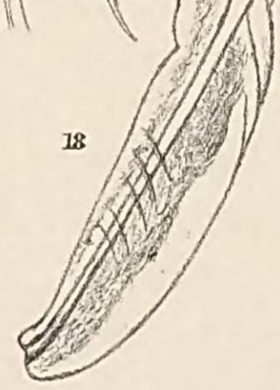

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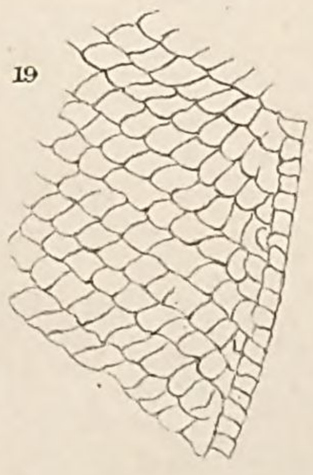

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EXPLANATION OF PLATE LXII.

PLATE LXII.

Conchœcilla lacerta (male).

Figure

1. Antennule and frontal tentacle.
2. Part of principal seta of antennule, with marginal cilia, more highly magnified.
3. Base of secondary branch of antenna.
4. Apical portion of mandible.

Conchœcia magna.

5. Shell of male, seen from left side, × 84.
6. Antennule and frontal tentacle of male.
7. Part of principal seta of same, more highly magnified.

7*a*. ,, ,, ,, ,, seen from side.

8. Secondary branch of antenna of male.
9. Foot of first pair (male).
10. Caudal lamina
11. Copulatory organ of male.
12. End of frontal tentacle, female.
13. Secondary branch of antenna, female.

Halocypris concha (male).

14. Shell; valves open and seen from within, × 24.
15. Frontal tentacle and antennule.
16. Secondary branch of antenna.
17. Mandible and palp.
18. Maxilla of first pair, with appendage.
19. Caudal lamina.

Streptoleberis javosa.

20. An imperfect caudal lamina.
21. One of the ungues of the same.



G. S. Brady. del.
A. M. Norman del. figs. 20, 21.

Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LXIII.

PLATE LXIII.

Conchœcia obtusata.

Figure

1. Shell of female, seen from right side, × 40.
2. ,, ,, ,, ,, below, × 40.

Microconchœcia Clausii.

3. Shell of female, seen from right side, × 80.
4. Mandibular plates of same.
5. Antennule and frontal tentacle of male.
6. Armature of principal antennular seta, male.
7. Antennule and frontal tentacle, female.
8. Secondary branch of antenna, male.
9. Copulatory organ of male.

Paradoxostoma affine.

10. Shell, seen from left side, × 100.
11. ,, ,, ,, above, × 100.

Paradoxostoma inflexum.

12. Shell, seen from left side, × 100.
13. ,, ,, ,, above, × 100.

Cythere semiovata.

14. Shell, seen from left side, × 100.
15. ,, ,, ,, above, × 100.

Cytherura bodotria.

16. Shell, seen from left side, × 100.
17. ,, ,, ,, above, × 100.

Cytherura mucronata.

18. Shell, seen from left side, × 80.
19. ,, ,, ,, above, × 80.

Cytherura cornuta.

20. Outline of shell (young), seen from left side, × 120.

Cytherura nigrescens.

21. Outline of shell (young), seen from left side, × 120.

Ilyocypris Bradii.

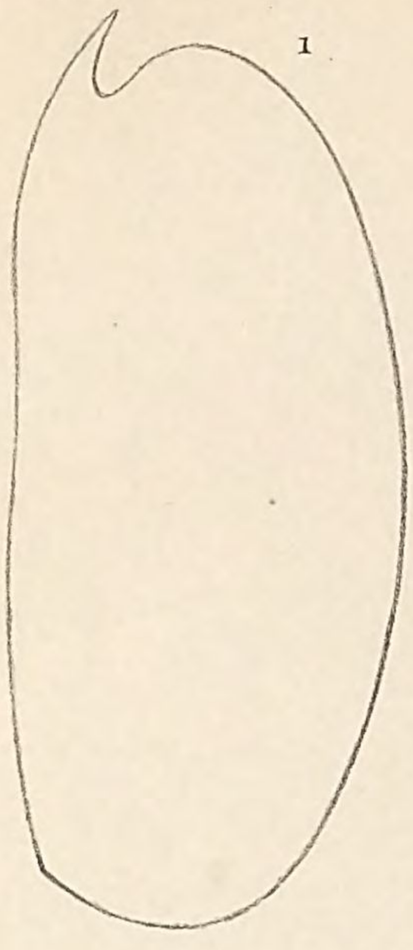
22. Antennule.
23. One of the caudal rami.

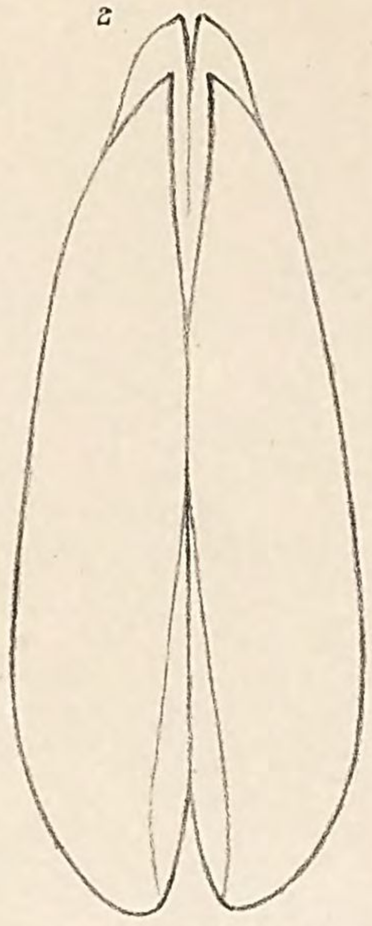
Candona pubescens.

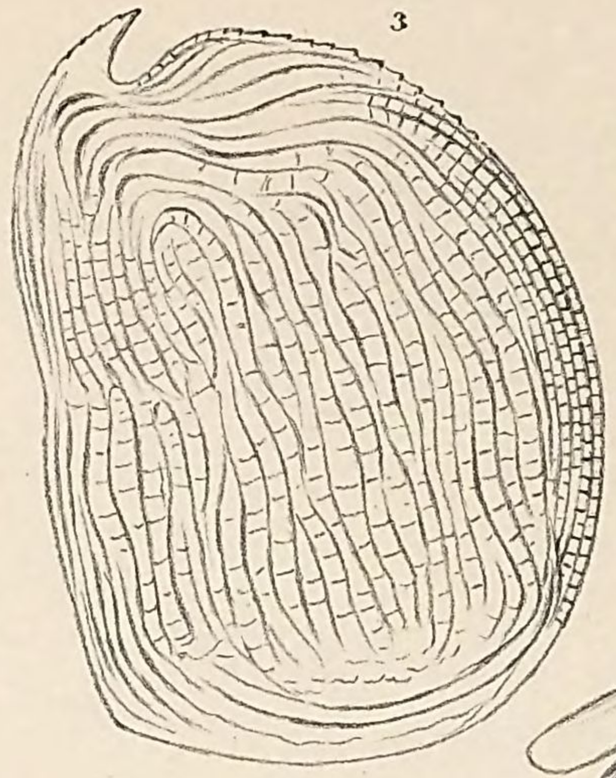
24. One of the caudal rami.

Candona Zenkeri.

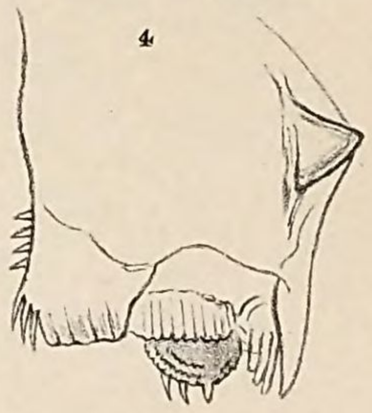
25. One of the caudal rami.

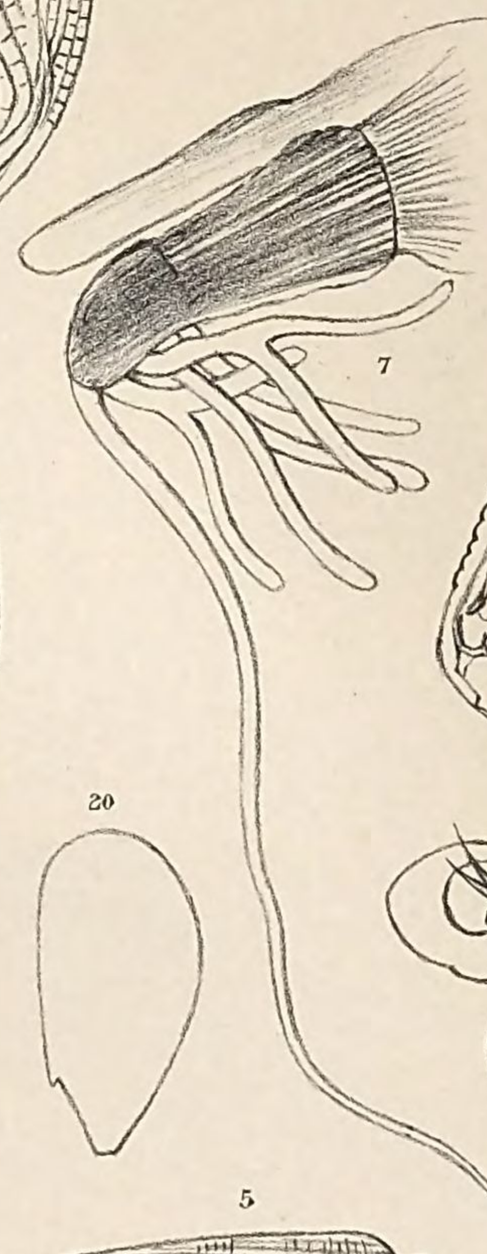






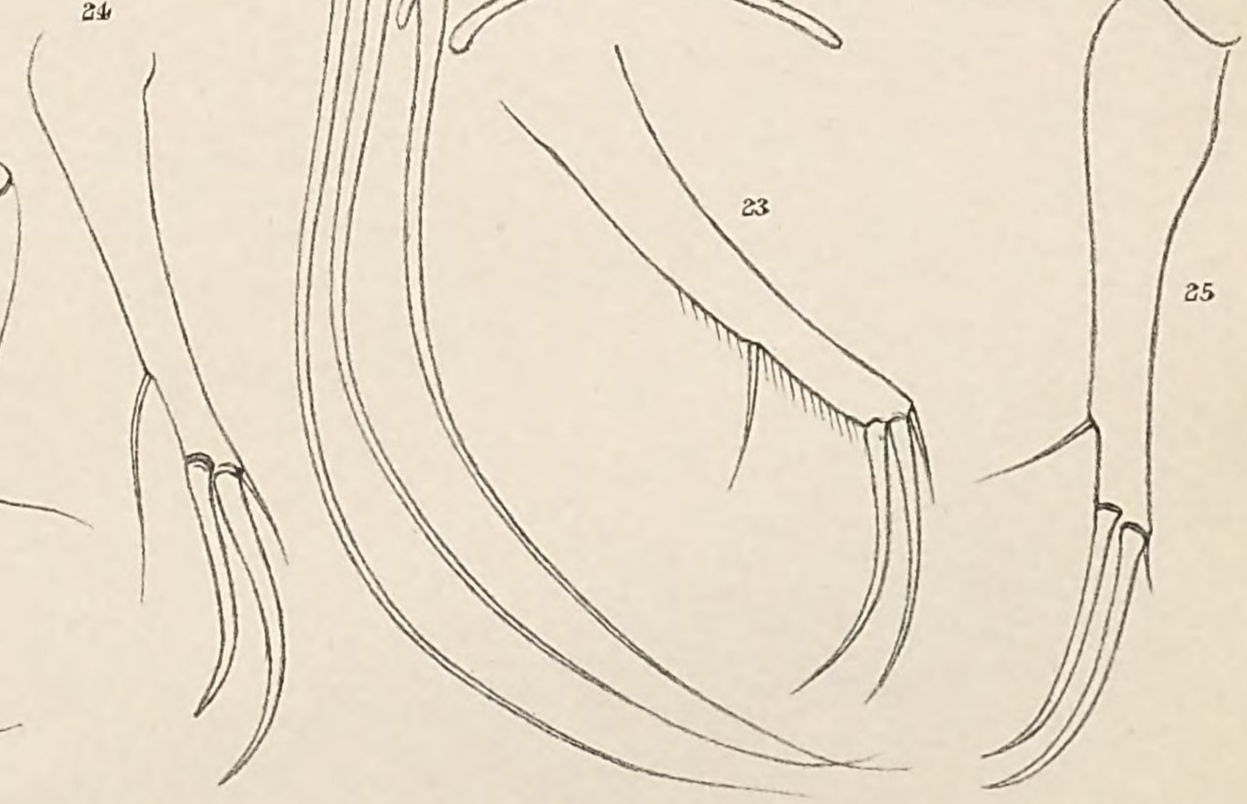




















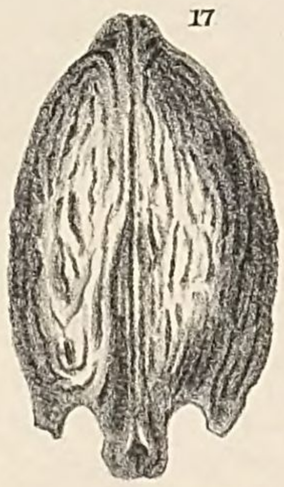
















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Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LXIV.

PLATE LXIV.

Conchœcissa armata (female ?).

Figure

1. Shell, valves open, × 25.
2. Reticulation of anterior margin of shell, more highly magnified.
3. Frontal tentacle.
4. End of mandible of left side (?).
5. ,, ,, oblique view, right side (?).

Conchœcia Haddoni.

6. Shell of female seen from left side, × 40.
7. Reticulation of anterior margin of shell.
8. ,, of central portion of shell.
9. Capitulum of frontal tentacle of female.
10. ,, ,, ,, male.
11. Labrum (upper lip).
12. Biting plate of mandible of female.
13. ,, ,, ,, male.
14. Spinous armature of a part of the principal seta of antennule, ♂.
15. Secondary branch of the right antenna of male. (*a*) Apex of hooked process of the same.
16. One of the caudal laminæ.

Cypris incongruens (male).

17. Second maxilla of left side.
18. Verticillate sac.

Pionocypris vidua.

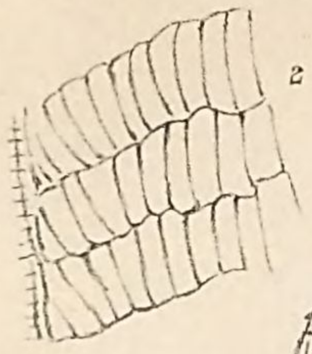
19. Caudal rami.

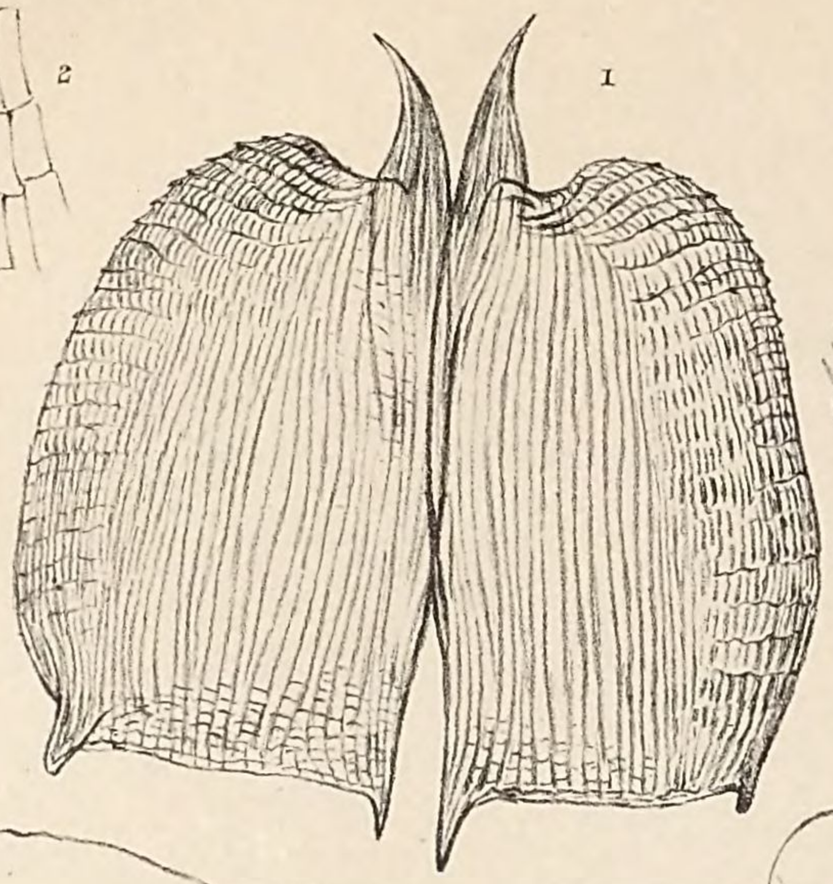
Candona pubescens.

20. Second maxilla of ♂, right side.
21. Shell structure.

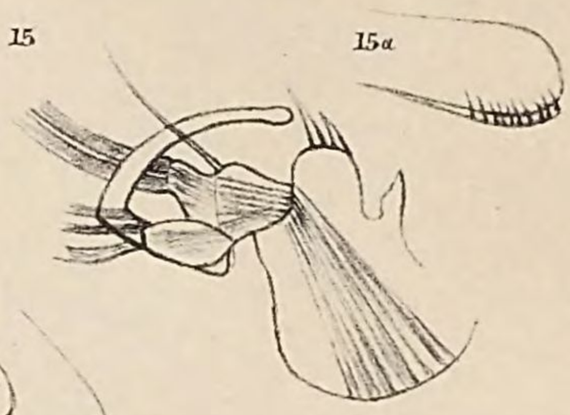
Conchœcilla daphnoides.

22. Entire animal, seen from the left side. (Specimen taken off Achill Head, Ireland.)

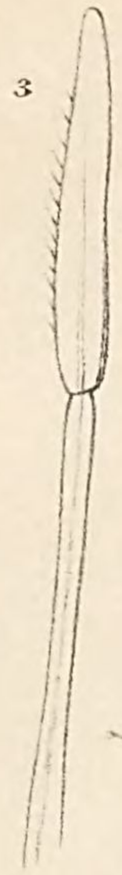

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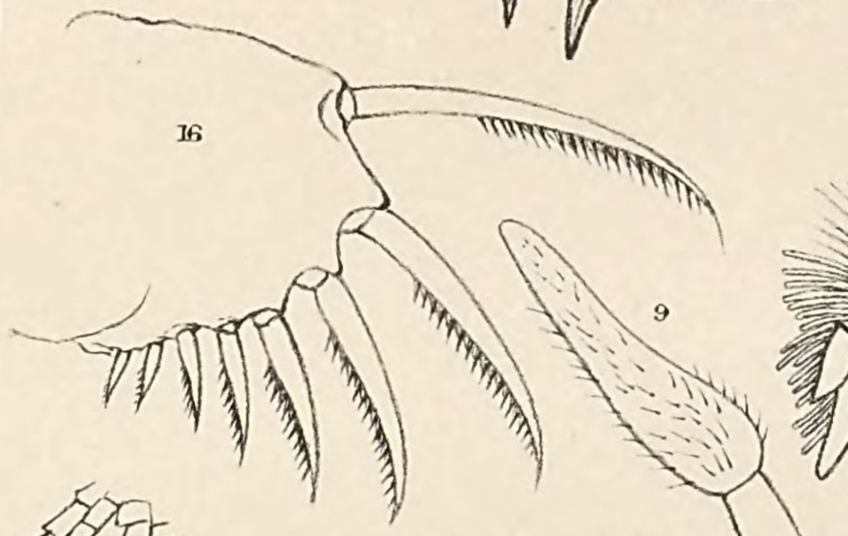

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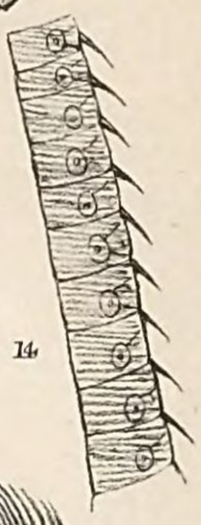
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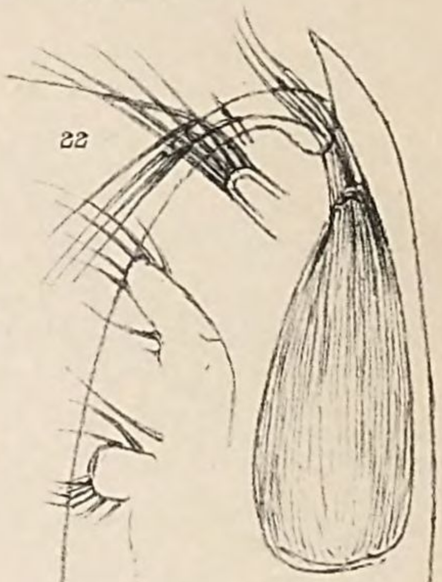
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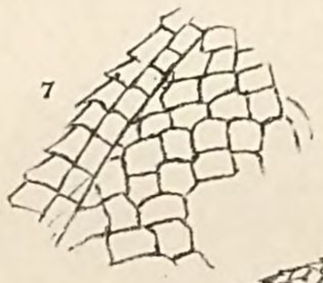

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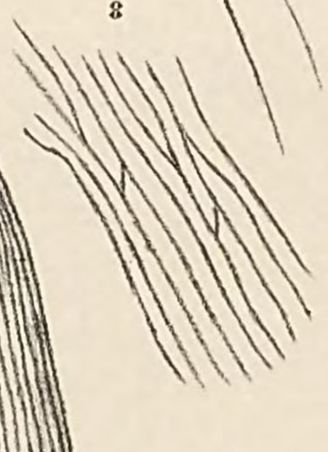

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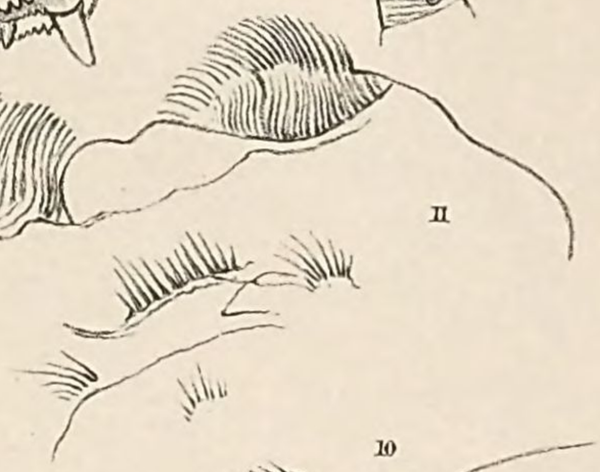

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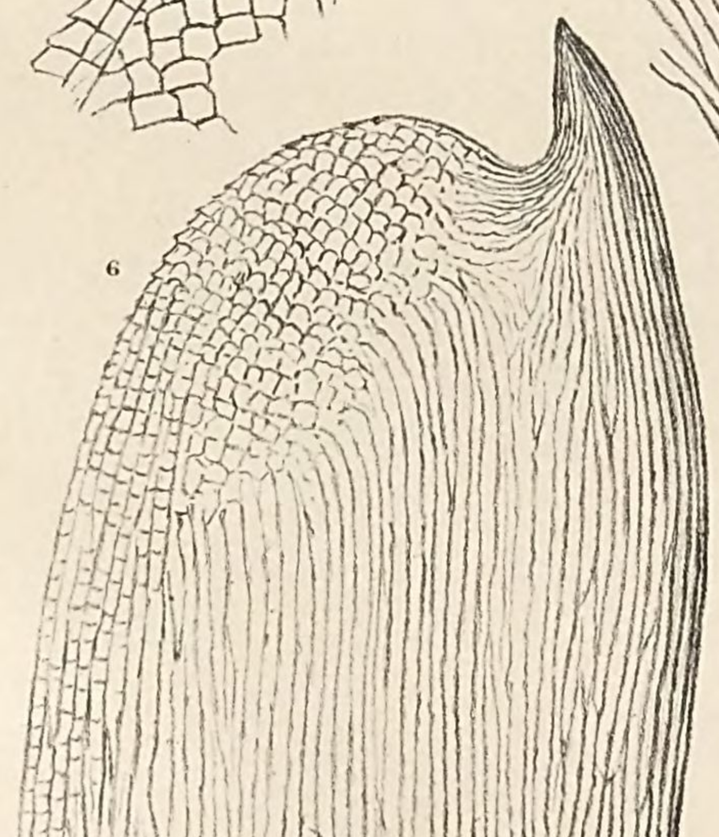
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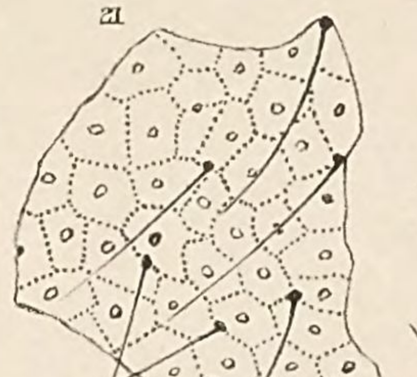

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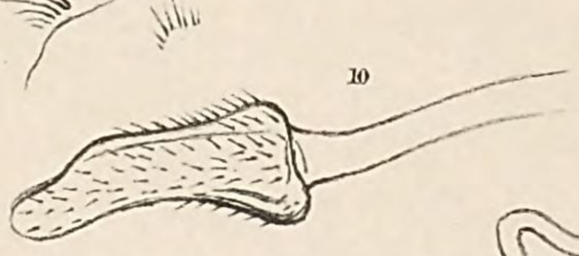

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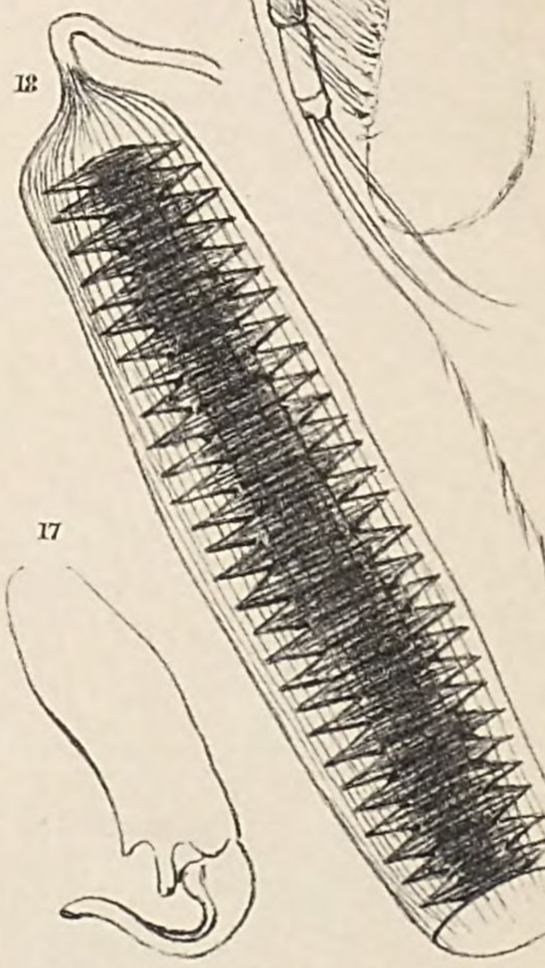

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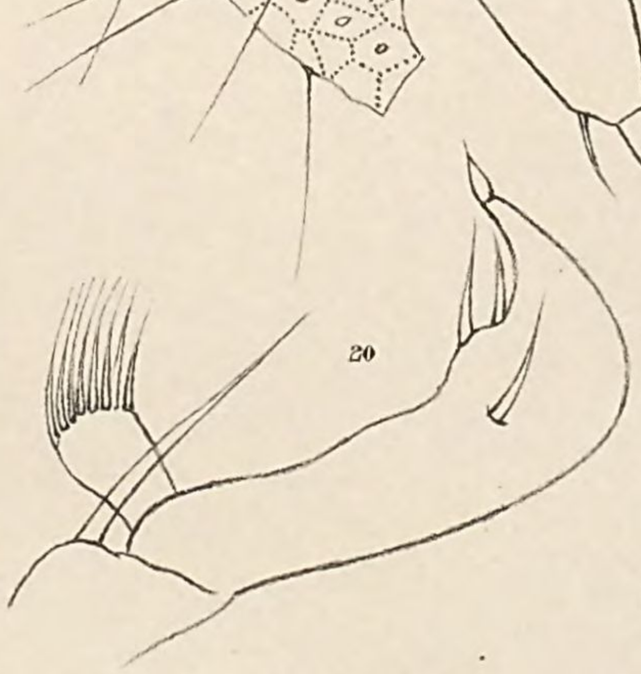

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EXPLANATION OF PLATE LXV.

PLATE LXV.

Conchœcilla lacerta.

Figure

1. Shell, seen from right side, × 25.
2. ,, ,, ,, above, × 25.
3. Posterior extremity of same, more highly magnified.
4. Shell structure near posterior extremity.
5. Frontal tentacle and antennule.
6. Antenna.
7. Mandible and palp.
8. Part of first foot.
9. First maxilla (distal portion).
10. Last foot.

Conchœcia elegans.

11. Female, seen from right side, × 40
12. Frontal tentacle and antennule of male.
13. ,, ,, ,, ,, ,, female.
14. Antenna of male.
15. First foot of female.
16. ,, ,, ,, male.
17. Mandible of female.
18. Maxilla of first pair, female.
19. ,, second pair, male.
20. Foot of last pair, male.
21. Caudal laminæ.
22. Copulatory organ of male.



G. S. Brady, del.

Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LXVI.

PLATE LXVI.

Cytherella abyssorum.

Figure

1. Shell of female, seen from left side, × 50.
2. ,, ,, ,, ,, above, × 50.
15. Second maxilla, with branchial lamina (female).

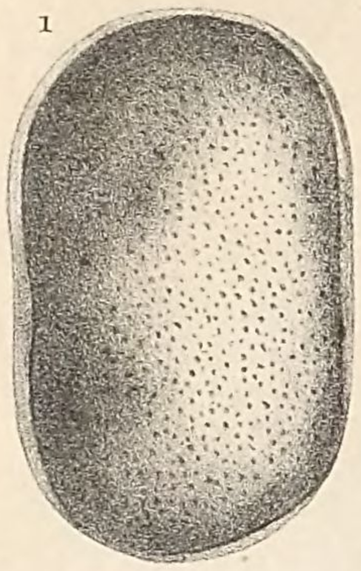
Cytherella lævis.

7. Shell of female, seen from left side, × 40.
8. ,, ,, ,, ,, above, × 40.

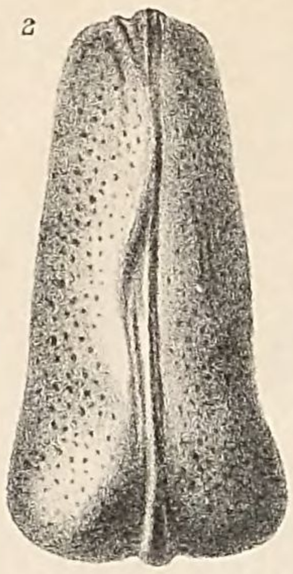
Cytherella serrulata.

3. Shell of female, seen from left side, × 40.
4. ,, ,, ,, ,, below, × 40 (with ova).
5. Shell of male, seen from left side, × 40.
6. ,, ,, ,, ,, above, × 40.
9. Muscle-spots.
10. Antennule.
11. Antenna.
12. Mandible and palp.
13. First maxilla, female.
14. Second maxilla of male, without branchial lamina.
16. Third maxilla of male, with branchial lamina.

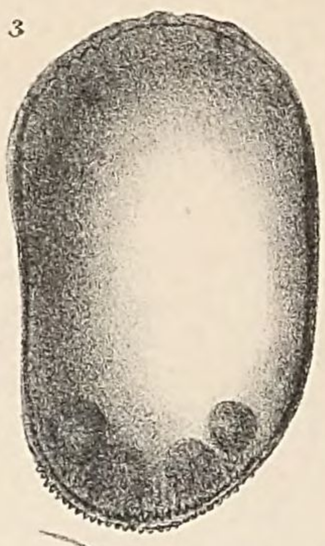
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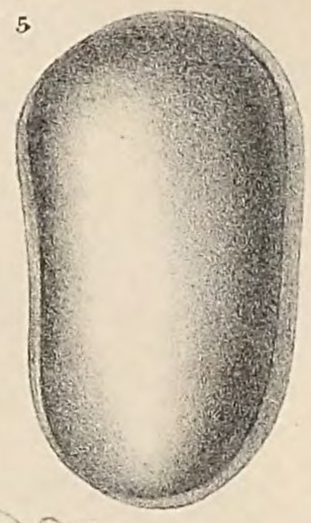
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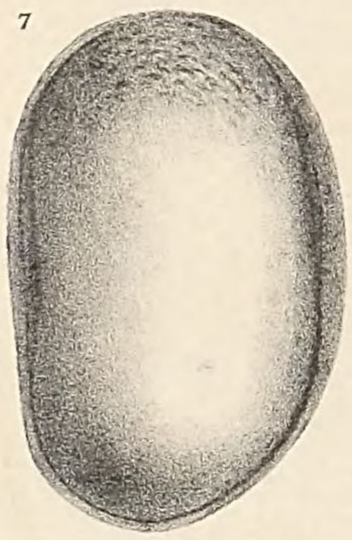
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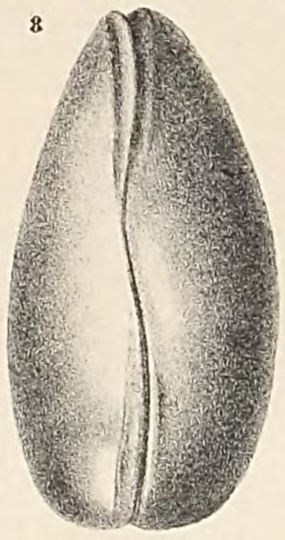
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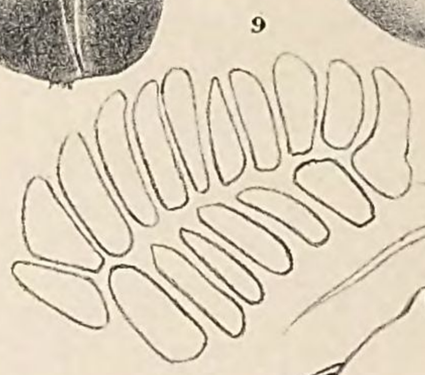
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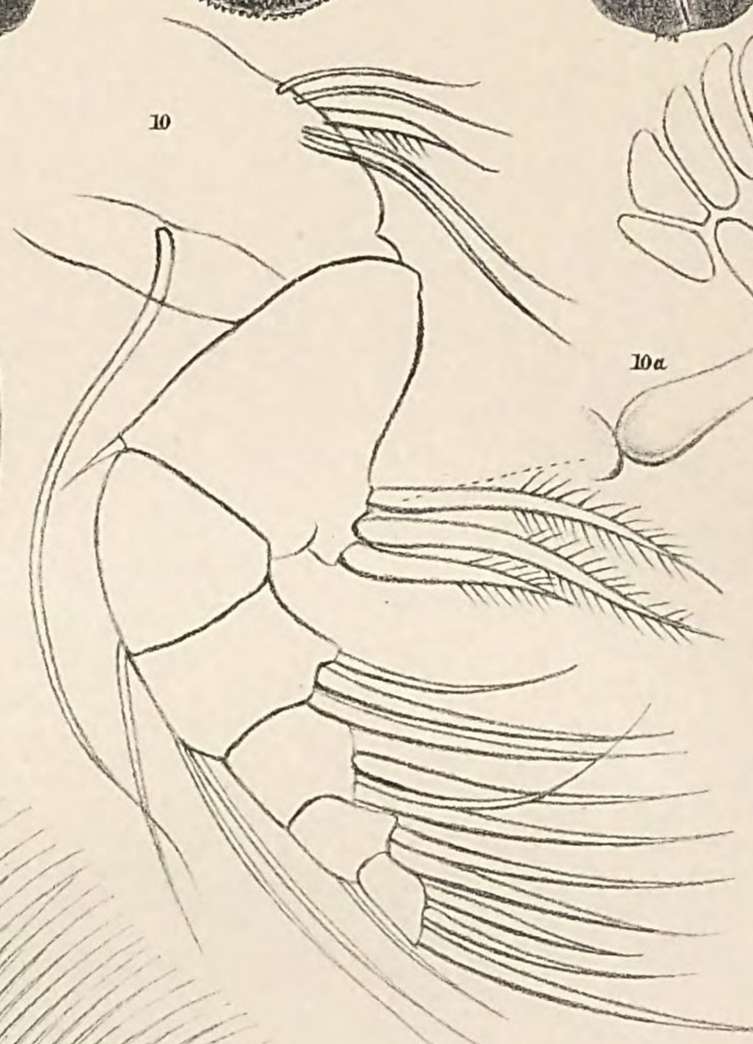
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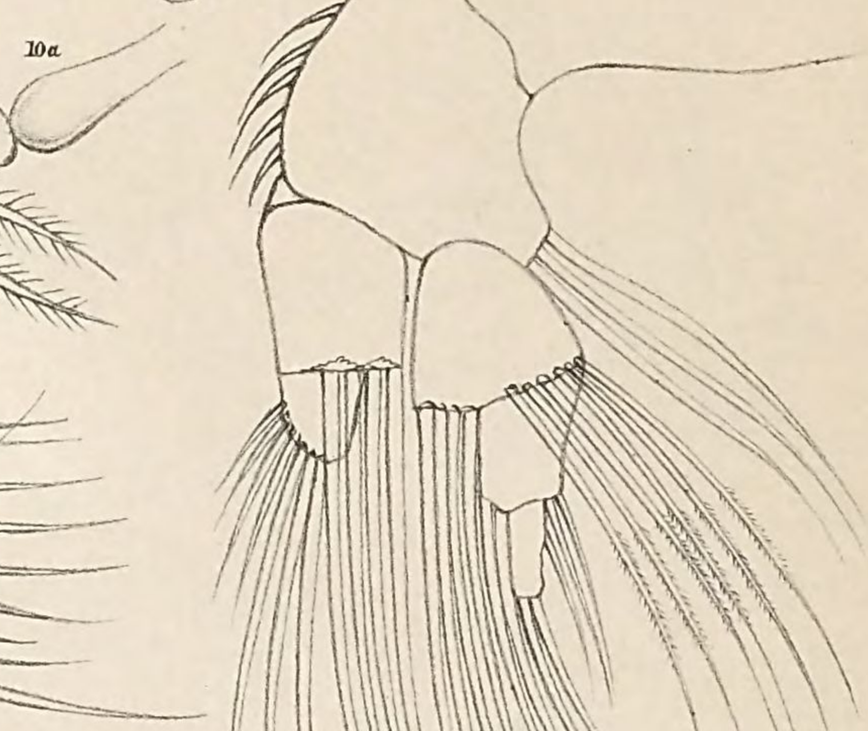
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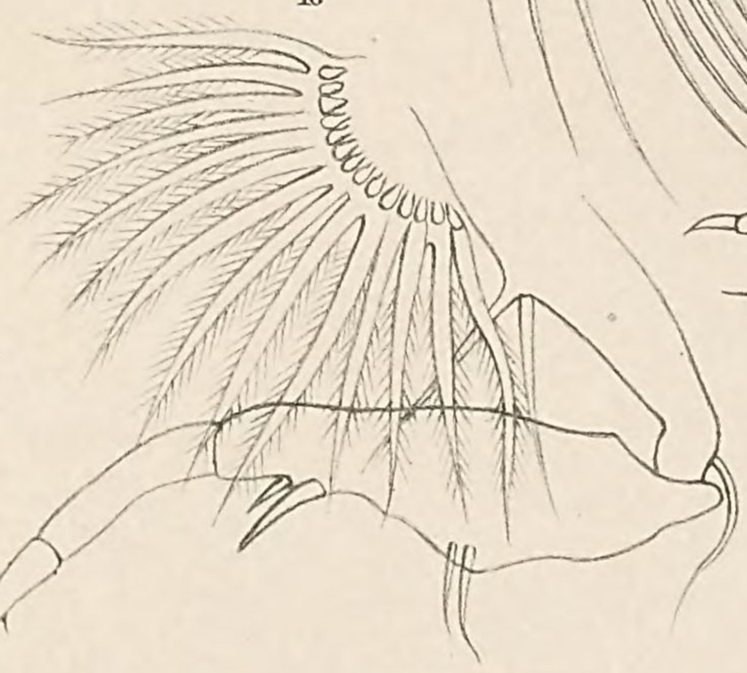


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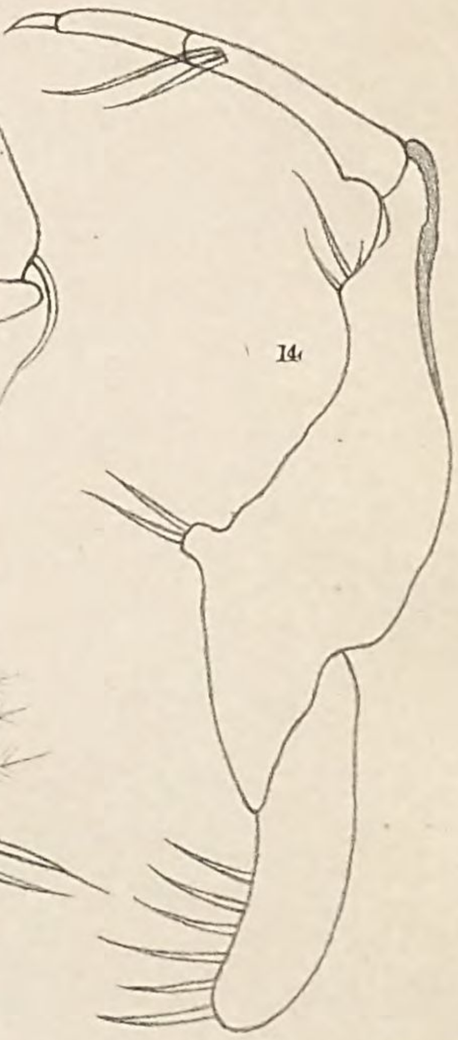
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EXPLANATION OF PLATE LXVII.

PLATE LXVII.

Polycope orbicularis (female).

Figure

1. Antennule.
2. Antenna.
3. First maxilla.

Polycopsis compressa (female).

4. Antennule and frontal cilia.
5. Mandible and palp.
6. Caudal lamina.
7. Teeth of anterior margin of shell, × 200.
8. Sculpture of shell, × 200.

Polycope punctata (female).

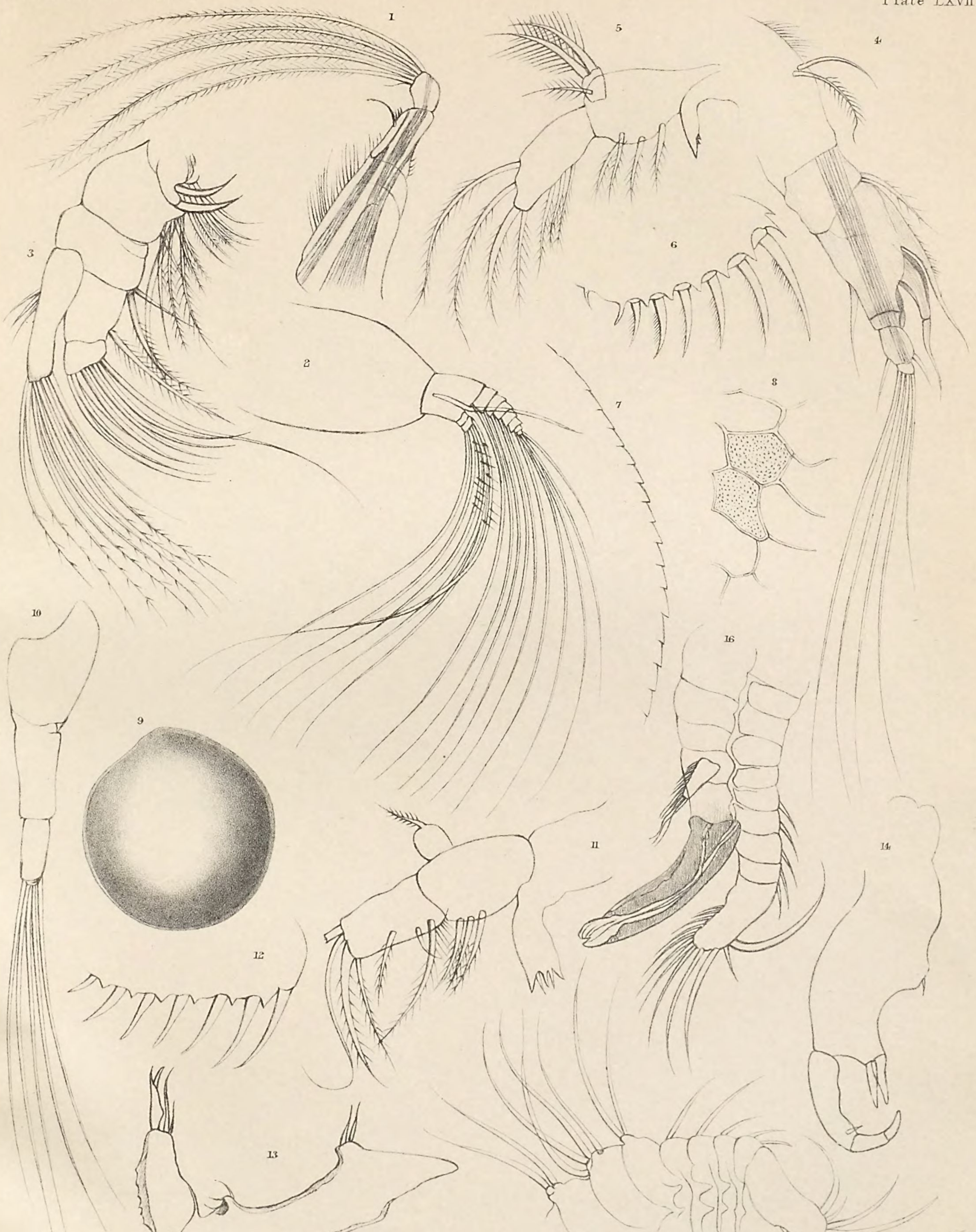
9. Shell, seen from left side, × 60.
10. Antennule.
11. Part of mandible and palp (a seta broken).
12. Part of caudal lamina.

Cytherella abyssorum.

13. Second maxilla, male.
14. Third ,, ,,

Cytherella serrulata.

15. Abdomen and tail, female.
16. ,, with copulatory organ, male.



G. S. Brady. del.

Geo. West & Sons lith. et imp.

EXPLANATION OF PLATE LXVIII.

PLATE LXVIII.

Candona glacialis.

Figure

1. Shell of female, seen from left side, ... × 30
2. ,, ,, ,, ,, above, ... × 30

Cypria lacustris.

3. Shell of female, seen from left side, ... × 80
4. ,, ,, ,, ,, above, ... × 80

Limnicythere inopinata (*incisa*, Sars).

5. Shell of female, seen from left side, ... × 84
6. ,, ,, ,, ,, above, ... × 84

Candona pubescens.

7. Shell of female, seen from left side, ... × 55
8. ,, male, ,, ,, ,, ,, ... × 55
9. ,, ,, ,, ,, above, ... × 55

Cytheridea monensis.

10. Shell, seen from left side, ... × 84
11. ,, ,, ,, above, ... × 84

Candona Zenkeri.

12. Shell of female, seen from left side, ... × 56
13. ,, ,, ,, ,, above, ... × 56

Candona stagnalis.

14. Shell of female, seen from left side, ... × 56
15. ,, ,, ,, ,, above, ... × 56
16. ,, male, ,, ,, right side, ... × 56
17. ,, ,, ,, ,, above, ... × 56

Ilyocypris Bradii.

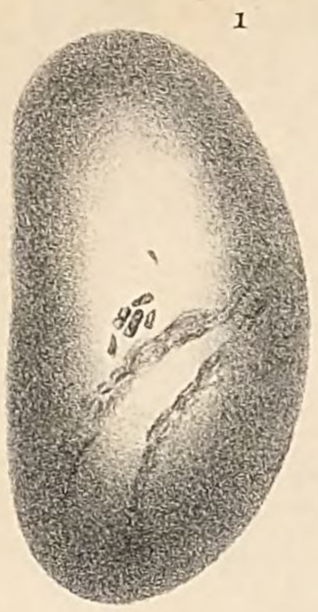
18. Shell of female, seen from left side, ... × 50
19. ,, ,, ,, ,, above, ... × 50

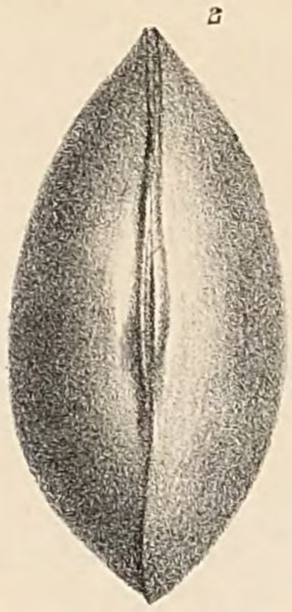
Ilyocypris gibba.

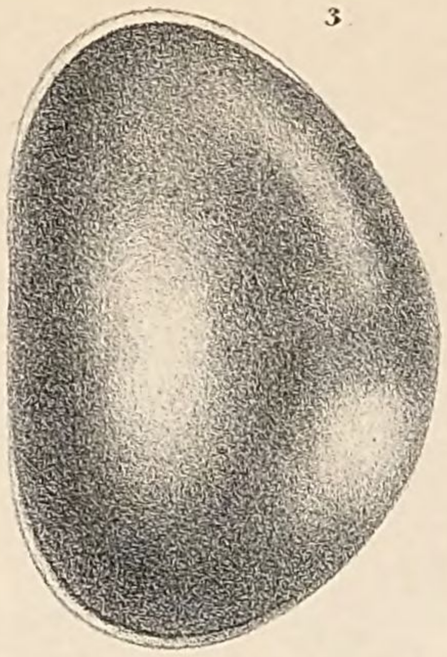
20. Shell of female, seen from left side, ... × 50
21. ,, ,, ,, ,, above, ... × 50

Cypris incongruens.

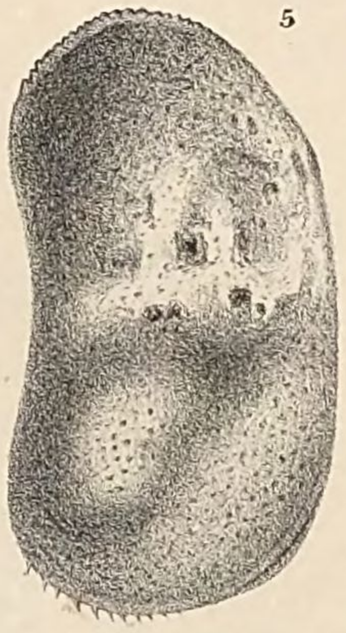
22. Shell of male, seen from left side, ... × 40
23. ,, ,, ,, ,, above, ... × 40

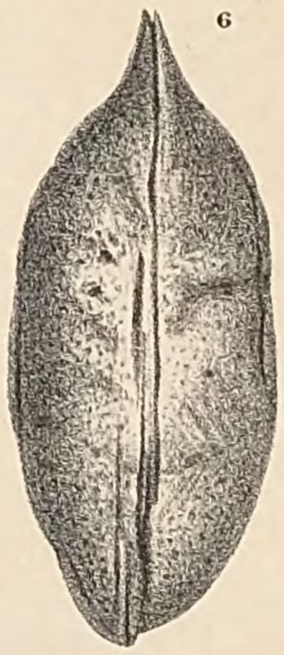

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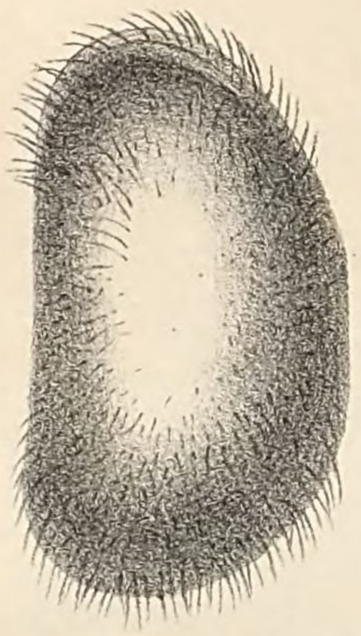

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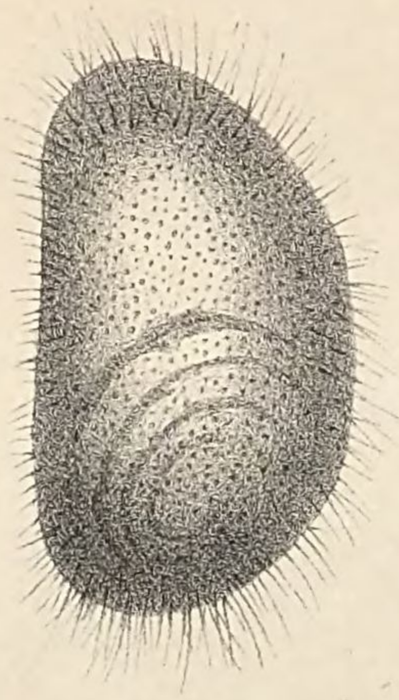

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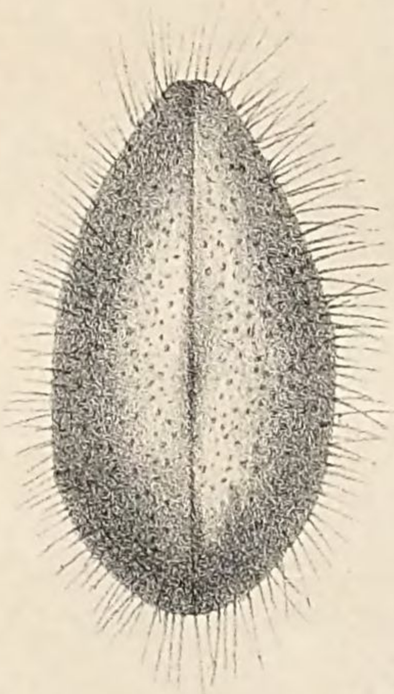

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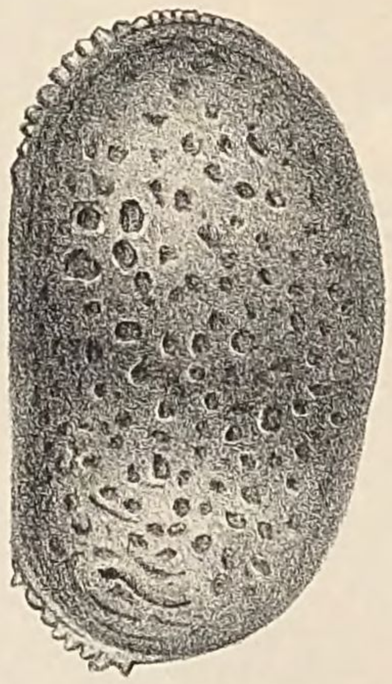

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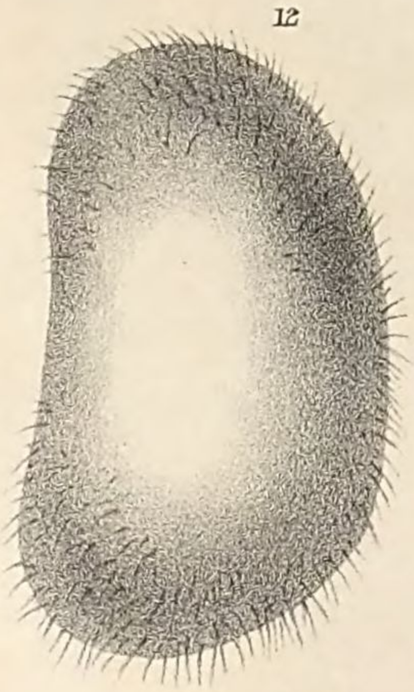

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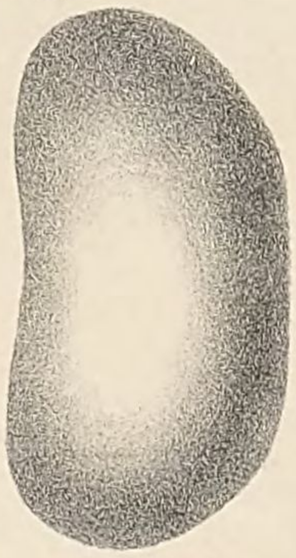

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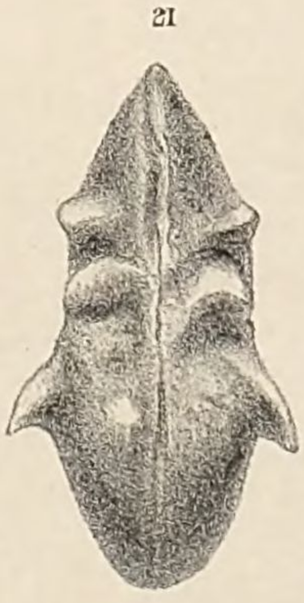

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G. S. Brady, del.

Geo. West & Sons lith. et imp.

[JULY, 1896.]

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME V.—(SERIES II.)

Abgegeben von Sternwarte Bamberg

XIII.

A MAP TO SHOW THE DISTRIBUTION OF ESKERS IN IRELAND.

BY PROFESSOR W. J. SOLLAS, LL.D., D.Sc., F.R.S.

(PLATE LXIX.)

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
WILLIAMS AND NORGATE,
14, HENRIETTA STREET, COVENT GARDEN, LONDON;
20, SOUTH FREDERICK STREET, EDINBURGH; AND 7, BROAD STREET, OXFORD.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK.
1896.

XIII.

A MAP TO SHOW THE DISTRIBUTION OF ESKERS IN IRELAND.

By PROFESSOR W. J. SOLLAS, LL.D., D.Sc., F.R.S.

(Plate LXIX.)

(COMMUNICATED BY PERMISSION OF THE DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY.)

[Read February 20, 1895.]

Introduction, Personal.

In the summer of 1893, my friend Mr. Praeger and I left Dublin for Maryborough to examine the remarkably fine esker which occurs near that town.* The writings of Jukes had inspired us with the idea of the marine origin of eskers, and we were persuaded that it only required careful search to discover traces of marine organisms. We searched intently from early morning to late evening, but without success; not a trace of a shell rewarded our efforts, and this, notwithstanding the favourable character of much of the material composing the esker, which, from its fineness and somewhat argillaceous nature, was well fitted for the preservation of fossils, had these, at any time, been present.

This result, being in general harmony with that obtained by other investigators, will probably not be considered surprising; nor were we so much impressed by it, as by certain positive characters, which, although we had frequently seen eskers before, we now seemed to perceive for the first time. These were the definite form of the long narrow ridge, and, more particularly, the steepness of its slopes, and the looseness of its material, which evidently rested at an angle not far different from that of its angle of repose.

This single instance was in itself sufficient to dissipate all notions of a marine origin. We were already familiar with the fact that such ridges are nowhere known to be in process of formation by the sea at the present day; but we now perceived that the fact of loose material resting at approximately its angle of repose was incompatible with the idea of its deposition beneath the waters of a sea by means of currents.

The question that pressed itself for solution was this:—How could a ridge of

* The northern part of this esker is shown within the southern border of Pl. LXIX., south of Mountmellick.

loose material have been deposited from water, as the structure of this one clearly proves it to have been, and yet have acquired such steeply sloping sides? The only answer that could be given was that, during deposition, boundary walls must have existed by which it was held up. What, then, were these walls? Might they not have been a lateral extension of the esker itself, a lateral extension so wide as to constitute an alluvial plateau? An answer in the affirmative has been given by at least one Irish geologist, Mr. M. Harrison;* but such a solution has been rejected by others, including the late Professor Jukes, and as it seems to me on very sufficient grounds; for, in the first place, the existing drainage system of the country is not related to the eskers in a manner which would suggest such an explanation; and, in the next place, the structure of the eskers themselves is definitely opposed to it, since the stratified material of which they consist is frequently arranged so as to dip parallel to the sides of the ridge, and, in addition, the separate ridges sometimes unite so as to inclose deep hollows between them, which could not, by any possibility, have been excavated by a stream.†

It is impossible to explain an esker as the denuded remains of a plateau; and again we inquire what were the retaining walls which held it up during its deposition? Whatever they were, they no longer exist, and have utterly vanished from the face of the land. The only substance at all likely so to behave is ice. But we have independent evidence that the whole of Ireland was at one time buried under a system of confluent glaciers, and it is known that streams of water flow over, under, and through such ice-sheets. Let the channel of some such stream become choked up by *débris*, and a cast of it will be formed in sand, gravel, and pebbles, which, on the disappearance of the ice, might form a ridge in all respects similar to an esker.

If such an explanation were on the whole true, it would follow that an individual esker should resemble, in its wanderings over the country, the course of a river, it should branch and meander; and similarly a system of eskers, if such should exist, as might naturally be expected, should often repeat the characters of a river system. To see whether this was the case, I prepared from the published maps of the Geological Survey the maps which this Paper is written to illustrate, and on reference to it the resemblance, which we have deduced, will be manifest at a glance.

It is now clear why we did not succeed in finding marine shells at Maryborough; their absence is just what our present explanation would lead us to expect.

The next step was to acquire a knowledge of the literature of eskers; and from this it appears that a similar explanation to that we have just attained

* M. Harrison: *On the Origin of Eskers.*—Proc. Belfast Field Club, ser. 2, vol. i., p. 100, 1875. In Sweden, this view had already been proposed by Törnebohm and others.

† Jukes' *Memoirs of the Geological Survey*, Nos. 98, 99, 108, 109, p. 8.

had already, over twenty years previously, been suggested by Professor N. H. Winchell in America, and by Dr. D. Hummel in Sweden in 1874.

If by the foregoing personal account I admit myself to have been twenty years behind the time, I willingly make the confession for the sake of what appears to me a fact of some interest, viz. that independent observers, studying eskers in three different countries, have been led independently, by personal investigation, to a fundamentally similar interpretation of these puzzling geographical features.

Literature of the Subject.

Ridge-like hills, which owe their origin to glacial action, are of more than one kind, and it is necessary to distinguish between them. The first and most important step was taken by the Rev. Maxwell Close in 1865, who separated, under the name of "Drumlins," those ridges which consist of unstratified boulder clay from those formed of water-worn material. To these latter he restricted the term "Esker."*

A further distinction has been suggested by Professor T. C. Chamberlin,† who proposes to divide eskers into two classes, the one containing those ridges that run with the slope of the ground—these he calls åsar—and the other, those that run transversely to the direction of the glacial movement, and which are usually associated with terminal moraines; these alone are to be called kames. The distinction may certainly be recognised in the case of Irish eskers, at least as regards their relation to the form of the ground or the movement of the ice; but not, so far as I am aware, as regards their association, or otherwise, with terminal moraines. In any case the term "esker" is too deeply rooted in the nomenclature of Irish geology for us to abandon it without inconvenience; possibly in Scotland greater readiness will be displayed in restricting the meaning of "kame."‡

* *Notes on the General Glaciation of Ireland*, by the Rev. Maxwell H. Close (1865).—Journ. Roy. Geol. Soc. of Ireland, vol. i., p. 207, 1867.

† *The Terminal Moraine of the Second Glacial Epoch.*—Third Annual Report U.S. Geol. Survey, p. 300, 1883.

‡ On referring to Dr. J. Geikie's *Ice Age* (3rd edition), I find, however, that while the term "kame" is retained, it is proposed to abandon "esker" for "ås." On page 746 we find the following:—"As between the alternate terms 'ås' and 'esker,' the former has the sanction of priority, and is the local term for the great Scandinavian type. Notwithstanding this, the term esker is growing into favour among American Glacialists, doubtless for phonic reasons." I regret that I am unable to admit the priority of the term "ås" without further information. The series of esker-groups to be described later on is part of what was formerly called by the general name of Esker Riada. O'Donovan, in his translation of the *Annals of the Four Masters* at A.D. 123, where Esker Riada is mentioned, says of it—"This is a line of gravel hills extending from Dublin to Clarinbridge in the county of Galway. It is mentioned in ancient Irish MSS. as reaching from Dublin to Clonard, thence to Clonmacnois and Clonburren, and

Finally the late Professor Carvill Lewis has designated as marginal kames* certain eskers in Pennsylvania which are associated with the terminal moraine, and which were formed by a subglacial drainage in the direction of the local valleys, but in the opposite direction to the flow of the ice.

The literature treating of the origin of eskers is very extensive; but we shall considerably shorten our account if we dispense, as we fairly may, with the treatment of those theories which invoke the action of the sea as a probable cause. Professor Carvill Lewis has, indeed, summarily dismissed such theories as "antiquated," and they are certainly too well known to require fresh presentation. It may be further remarked that they account for scarcely any of the features which are most characteristic of eskers, and they are inconsistent with some known facts. Since explanations depending on the effects of glacial rivers are free from these objections, there is every reason why we should restrict our attention to them.

The first to propose, or rather to adumbrate, a glacier theory of eskers was Mr. N. H. Winchell.† His words are as follow:—"The effect of such a persistent obstruction [*i.e.* of a ridge of Niagara Limestone] beneath the glacier must have been to fracture the ice profoundly, those parts toward the east and toward the west settling gently away from the uplifted centre. Into these crevasses the drift would fall, and through them streams of water would flow. The result would be an extraordinary accumulation of coarse and assorted drift materials, which, after the complete withdrawal of the ice, would lie in irregular knolls and short ridges in places where such streams formerly existed. This is the origin of a great many short, but steep and narrow, gravel ridges in the North-western States outside Ohio, which are known locally as 'Devils' Backs,' or 'Hogs' Backs.'" . . . "They generally rise from 25 to 40 feet, with slopes as steep as such material can be piled into. On either side there is usually a low, swampy tract, from three to ten rods wide, or sometimes of indefinite width and form, the ridge being in some cases not more than 20 feet across on the summit. The largest boulders are sometimes seen on the very top of the ridge."

It is unfortunate that Professor Winchell does not identify these gravel ridges with eskers, kames, or åsar; the more so, as some pages further on (p. 181), he

thence to Meadhraighe, a peninsula extending into the Bay of Galway." See also the (earlier) *Annals of Clonmacnois*, under Conn of the Hundred Battles, whose kingdom stretched southwards to the Esker Riada. The "phonic reasons" are certainly worth considering; every English-speaking geologist knows how to pronounce the word esker, but few seem to be aware of the correct pronunciation of åsar; it is not quite "osar" as seems to be generally supposed. The grammatical form is a still more serious objection to the use of the Scandinavian term, for we do not readily form our plurals in *ar*.

* *Marginal Kames.*—Proc. Acad. Nat. Sci., Philadelphia, 1885, p. 157.

† *The Surface Geology of North-Western Ohio.* By N. H. Winchell.—Proc. Amer. Assoc. Adv. Sci., vol. xxi., 1872 (1873), p. 165.

definitely mentions "ozars," only to explain them as due to "the constant breaking of the waves."

The same omission to connect the Ohio ridges with eskers occurs in later writings by this author.* At the same time there can be no manner of doubt that the features which Professor Winchell had under observation are true eskers, and therefore we must justly assign to him a share of the credit of first attributing to them a glacial origin.

In the same year Mr. James Shaw† described gravel hills in Illinois (which appear to be eskers, though this is not expressly stated), and attributed them to the combined action of glaciers and water.

Dr. D. Hummel‡ was the first to propose and elaborate a complete and consistent theory of eskers. An excellent summary of this is given in Professor J. Geikie's *Ice Age*.§ The following account is taken from Dr. Hummel's memoir. The eskers on which the author bases his theory are those of Southern Sweden, and particularly those of the high ground, more than 400 feet above the sea-level, and so beyond the limits of the glacial submergence; in their case, consequently, an appeal to the action of the sea is excluded. The only other theory (with which the name of Törnebohm is most closely associated) making any pretence to explanation presupposes the existence of great plains of mud, through which rivers cut their way, forming valleys in which the gravel and sand of the eskers were deposited. By the subsequent removal of the mud, the eskers acquired their existing shape. Hummel remarks of this, that it is inconceivable that so much mud should have existed without leaving some trace behind; particularly as the form of the surface of the Swedish plateau is such as would be likely to prevent its complete removal. Traces of the mud-plain might certainly be expected to occur between the esker deposits and the underlying boulder-clay; but though the contact of the two latter can be plainly seen, there are no signs of the mud—on the contrary, the boulder-clay and the esker material pass into each other.

Stratified deposits covering the eskers are of rare occurrence and of inconsiderable extent: in tracts where they generally occur, one is accustomed to distinguish an interior part, or kernel, from an outer part or shell; the kernel is evidently contemporaneous with the ancient ice-sheet. This is shown by the intimate association of the Yoldia clay with the shell of the esker in the lowlands, and the occurrence of boulder-clay immediately below the kernel.

* *The Geological and Nat. Hist. Survey of Minnesota.*—First Annual Report for the year 1872 (1873), p. 62; and Second Annual Report, 1873 (1874), p. 194.

† *Geological Survey of Illinois*, vol. v., p. 108, 1873.

‡ *Om Rullstensbildningar*, by D. Hummel.—Bihang till K. Svenska Vet. Akad. Handlingar, Bd. II., No. 11, p. 3, 1874.

§ *The Great Ice Age*, 3rd edition, 1894, p. 172.

The connection of the eskers with the inland ice is, according to this author, more definitely shown by the following :—

1. The generally close correspondence between the direction of eskers and that of glacial striation. Both are related to the direction of the flow of the inland ice, and thus to the general slope of the land and its great valley systems. At the same time they may be independent of minor, but still considerable, inequalities of the ground.

2. The not uncommon transition, which may be traced between esker material and boulder clay, within the same system of eskers, or even within a single esker; in the latter case usually towards its highest-lying end.

3. The occurrence of great perfectly angular blocks of stone on, or within, the esker; or even of a superficial covering, not unlike terminal morainic material.

4. The occurrence of marked dislocations within the esker.

While these characters indicate a connection with the ice, there are others pointing no less clearly to the influence of running water; but not of the sea, as is shown by :—

1. The absence of marine shells from the kernel of the esker, which is sometimes beautifully stratified.

2. The common occurrence of false bedding, which rarely appears in the evidently marine deposits.

3. The rarity of stratified sheets overlying the kernel of the esker.

The notion that eskers might be of marine origin was suggested by their form, which appears to require the agency of some force acting at right angles to the direction of their length.

What is required is—

1. Running water acting with considerable force, and for a sufficiently long time.

2. A force acting at right angles to the direction of the esker.

Nothing but a melting ice-sheet can give us this.

The author then turns to Greenland, and cites Nordenskiöld to show that deep crevasses occur in the ice, and that considerable streams of water flow beneath it; and that its surface is undulating. The crevasses arise in consequence of the movement of the ice, and are greatest where the movement is most rapid; they run at right angles to the direction of movement; they are deepest in the middle of a flow, and diminish towards the sides.

As regards the bottom of an ice-flow, we know that tunnels exist there, produced by the action of air and water; and these may be quite general beneath

the inland ice. If we think of an ice-sheet melting away, we must picture the water, continuously produced on its surface, finding its way down to the bottom through crevasses, producing there tunnels, the size, form, and distribution of which will depend on the movement of the water; and this, in its turn, depends on the slope of the upper surface of the ice, its crevasses, and the slope of the underlying ground. Let a valley exist on the upper surface of the ice, then we might expect to find the tunnel below the ice taking the same direction as this valley; further, let a correspondence exist between the direction of the valley on the ice, and of a valley on the underlying ground. Then, from the sides of the ice valley, and at right angles to it, the water, streaming down, will proceed, maintaining its directions through the ice; the streams of water will meet somewhere in the mountain valley below the ice, and produce a powerful effect on its lower surface. Something similar might occur, independently of the relief of the ground, if the crevasses increased in depth towards the middle of the ice-flow, and diminished towards its sides.

Such streams of water must naturally occur and precipitate themselves in numberless places along the whole length of the ice valley; streams of water, also, coming from opposite sides, will meet along a line, more or less crooked, under the ice, and thus will arise a long extended vault, or row of vaults, in the bottom of the ice, running in the same direction as the ice valley.

Given the possibility of such action of the water on the bottom of the inland ice, and the explanation of the highland eskers becomes comparatively simple. The ground-moraine is exposed to the action of the flowing water; it becomes converted by degrees into a water-worn material, which is transported by the moving water to the glacier tunnel, and is forcibly pressed in, until the tunnel is filled with it; the lateral streams are compelled, then, to form a new tunnel by the side of the old; the new one is, in turn, filled up, and another excavated, and so on. The ice thus acts both by determining the movement of the water, and by affording a mould within which water-worn material is collected. The greater the thickness of the ice, and the greater the fall of water, the larger the sub-glacial tunnels, and the greater the dimensions of the eskers. On quite level tracts of boulder-clay the eskers attain no great height, but still present a plainly recognisable form, and are often bordered by peat-filled depressions at the sides.

These lateral depressions—esker moats—are very characteristic features; while in some places inconspicuous, in others they attain a considerable size, and not seldom form a large basin from which several eskers of well-defined form proceed. When not due to the form of the glacial tunnels, they may result from the excavating action of water, which, pouring down the sides of the ice, scours out the moat, and afterwards builds up the excavated material into the esker. Thus the moat might be the first stage in the formation of the esker.

The kettle-holes, which occur between two closely adjacent eskers, are probably due to the form of the bottom surface of the ice; those, however, which run down the middle of a single ridge are possibly a consequence of waterfalls through the ice. The interruptions of the eskers, their variation in height, and winding form, even within a well-marked valley, are all the natural result of changes in the number and strength of the lateral rivers. That the windings have been so well preserved may be due to the cessation of the movement of the ice, shortly after their formation, as a consequence of its melting.

The frequent deviation of eskers from the direction of the glacial striation is due to the ramifications of the ice valleys; and from these ramifications also result esker spurs and knots.

The absence of eskers from large wide valleys might be explained, in cases where the ice was not moving with the slope of the ground, by assuming that the watershed of the drainage on the ice ran along with, or across, the hollow of the underlying valley.

It is to be remarked that:—

1. Eskers usually proceed through valleys, even when these occur on plateaus.

2. The slope of the inland ice, if its thickness be comparatively small, is dependent on the slope of the ground, and the more so as melting proceeds.

3. Valleys in the land, particularly in high-lying tracts, exert an important influence on the position, or direction, of the ice-flow, or its depressions; the more especially as the whole movement of the ice in the latest times followed, in general, the large and regular valleys.

That exceptions to the above rules are numerous appears from a comparison of the direction of eskers and glacial striæ; and their significance is great, as by them, alone, can we obtain simple explanations of such facts as the following:—

The often obvious independence of the eskers and the slope of the ground, their great and numerous interruptions, their isolated position, the appearance they often present of having been very rapidly heaped together. These facts may be regarded as the effects of changes in, and on, the inland ice, and in the volume and velocity of the lateral streams.

That the ice and the subglacial rivers may have moved in contrary directions, for longer or shorter distances, is clearly shown by observations on the structure of some gravel deposits; the most beautiful example occurs between Hilleshult and Svensbygget (Halland). At the S.W. end, on the highest ground, this is extremely insignificant, and consists only of pebbles; its dimensions increase rapidly towards the N.E., but the material does not change until near Hilleshult; there the pebbles are fewer, the material is more water-worn, and there is more sand. This change of structure, on the whole, obtains less, if at all, in the definite

esker which winds along through the same great area of gravel. Since the water-worn material diminishes from S.W. to N.E., it is clear that the water flowed in this direction, while the glacial striæ show that the movement of the ice was from N.E. to S.W. The existing river now flows in the same direction as that which carried the gravel.

Hummel's famous Paper was followed by one equally well-known by Dr. Holst.* A short account (by Dr. Lindahl) of this Paper was published in the *American Naturalist*, vol. xxii, 1888, pp. 589 and 705. The author commences with a powerful criticism on the marine and mud-plain theories, which he has little difficulty in demolishing. He rightly points out that the mud-plain theory had, at least, the merit of perceiving that the esker required sustaining walls for its formation, and that these have since disappeared, and that it recognised the resemblance of an esker to a river deposit. [One may remark that the same material, viz. mud, was at one time invoked to do other duty, which has since been assigned to ice, such as transporting erratics and polishing and striating rock surfaces.] Holst fully recognises the merit of Hummel's theory so far as it depends on the presence of the inland ice, but he thinks it less fortunate in its details, particularly in assigning the origin of the eskers to tunnels below the ice. The formation of the subglacial tunnels, as described by Hummel, affords a fair opportunity for a damaging attack; but since the observations of Russel on the Malaspina Glacier, the whole treatment of this part of the subject, both by Holst and Hummel, appears speculative and artificial.

Dr. Holst then proceeds to explain his own views. On the melting of the inland ice, streams form upon its surface, which work back from the margin of the ice until they form ice-cañons; at the same time englacial drift (which is assumed to exist in considerable quantity) is set free, worn by running water into rounded gravel, and sorted and arranged in layers on the bed of the stream. Thus the englacial fragments, which lay near the upper surface of the ice, form the lower layers of the esker.

On the final melting of the ice the deposits in the river-bed remain behind as an esker. Nordenskiöld's description of a broad and deep river flowing on the surface of the Greenland ice is appealed to; and it is pointed out that the size of this river points to its having flowed for some distance before arriving at the place where it was observed. This river, a little lower down, certainly precipitates itself through the ice and disappears; but since crevasses depend on the movement of the ice, when the ice was melting away and becoming stationary, they would diminish and might almost disappear. Or if crevasses occur in the ice, they must be in union with one another and with the free margin of the ice;

* *Om de glaciala rullstensäsarne*, by N. O. Holst, Geol. Forens. i Stockholm Förhandlingar, Bd. III. p. 97, 1876 and 1877.

otherwise the water, which finds its way down in the higher regions to the bottom of the ice, will rise again to the surface at lower levels, and find its way over it.

The surface of eskers is sometimes covered with angular detritus; this is englacial drift, which was deposited in the last stages of the melting of the ice, when the running water was diminishing in strength.

Serious reasons are given for doubting the possibility of the formation of eskers from bottom moraine, at least in the manner supposed by Hummel.

As regards the kettle-holes of eskers, Nordenskiöld and Levin have suggested that water, streaming through the loose material of the esker, has carried away the fine sand, and so caused a settling of the residual material; thus forming a kettle-hole. This is very improbable. If such a process really occurred, we should expect to find at the bottom of a kettle-hole more large stones and coarser gravel than in other parts of the esker; but this is not the case. Kettle-holes are original, not super-induced, features of an esker. They may be explained as marking the position of islands of ice which stood up in the middle of the rivers of the ice-sheet.

A somewhat similar explanation will apply to the interruptions which so frequently occur in the course of an esker. A rapid accumulation of pebbles, for instance, may cause a diversion in the course of the river, so that instead of flowing through a cañon, it will proceed over or under the ice.

The author gives the following summary of his conclusions:—

1. Eskers were formed in running water.

2. No running water has the power to lift the contents of an esker to the considerable heights at which they so often occur.

3. The material must, therefore, have been lifted up by the ice, and from it carried down and heaped together in the eskers, somewhat after the fashion described above.

In the discussion following the reading of Dr. Holst's Paper, Nordenskiöld, Torell, and Törnebohm, took part; and it was pointed out that neither Hummel's nor Holst's theories accounted for all the peculiar features of an esker. Nordenskiöld called attention to the manner in which the great sand plains of North Asia are being denuded, as suggesting a possible explanation of the mode of formation of some eskers.

The first geologist in America to propound a general glacial theory of eskers was Warren Upham,* whose work has all the interest of independent discovery; for Winchell's explanation of a particular case, in no sense a general theory, was

* *On the Origin of Kames or Eskers*, by Warren Upham.—Proc. Amer. Assoc. Adv. Sci., 1876 (1877), p. 216.

obviously and naturally unknown to him. He was also unaware of the work of Hummel and Holst, this being then very recent, and moreover published in the Swedish language. Great credit further is due to Upham, owing to the fact that the phenomena are not so simple in New Hampshire as elsewhere, the eskers in that State being buried to a great extent beneath plains of alluvial deposit. I give this author's theory in his own words:—"Through the whole glacial period rivers probably existed, to some extent, beneath the ice; but their volume and strength . . . greatly increased during the final melting of the ice-sheet. In many instances these probably filled deep channels along lines of depression upon the surface of the glacier, which, at the last part of the melting, would coincide nearly with our present valleys; or oftener, probably, they formed for themselves great tunnels beneath the ice, seeking, of course, the lowest land for their route. By these glacial rivers, which flowed beneath, or on, the ice, discharging the water supplied by its melting, there were deposited, from the low water of winter, layers of sand, and from the strong currents of summer layers of gravel, often very coarse, which would be very irregularly bedded, here sand and there gravel accumulating, and, without much order, interstratified with each other. At the melting of the ice-walls on each side of these glacial rivers, the materials, which had collected to a great depth in their channels, were left in long ridges, a section of which would show an irregular anticlinal stratification. . . . Mounds or irregular short ridges . . . have probably resulted from the rapid deposition of these rivers as the last of the glacier was melting away, ridges and irregular masses of ice having existed where there are now hollows or ponds. These irregular accumulations of sand and gravel were many years ago attributed to similar causes by Dr. Edward Hitchcock, who accordingly named them moraine terraces. The occurrence of occasional angular boulders enclosed within, or lying on, the surface of kames is readily explained, as the course of the rivers was probably in most cases beneath the glacier, and they would be dropped from the melting of the ice overhead. From explorations in the Alps and Greenland we know that streams in summer are found flowing on the surface of glaciers, and that falling through crevasses these gather to form considerable rivers beneath the ice."

In the year 1877, the second edition of "The Great Ice Age," by Professor James Geikie, was published. It contains a notice of Holst's views, and an account of Hummel's theory, which the author, abandoning the marine theory, accepts.

Warren Upham* published a full and complete account of the eskers of New Hampshire in the following year. In this he considerably modifies the views he had at first expressed, so that they now more closely resemble those of Holst than

* *The Geology of New Hampshire*, 1878.

of Hummel. Thus, while admitting that in some cases eskers may have been formed by sub-glacial streams, he considers that, in general, the streams were super-glacial. He thinks that the deposition of the eskers took place chiefly at the mouths of these rivers, and extended along the valleys as fast as the ice-front retreated; and finally he no longer regards the large angular erratics, occasionally associated with eskers, as having been left behind by a melting glacier, but as dropped from floating ice.

In the same year Professor Newberry* describes the kames of Ohio as differing in some respects from typical eskers. "They occupy a topographical position which makes it impossible that they should have been the beds of rivers; for they form a belt along the summit of the divide between the lake-basin and the Ohio valley, all the way across the State"; and he concludes that they "have been formed by the action of water on the morainic material of the Erie clay"; but "how the necessary floods could be produced, there, is a difficult problem."

A valuable contribution to the study of eskers was published by Professor G. H. Stone in 1881.† Briefly summarised, Mr. Stone's results are as follows:—The eskers of Maine are found at all elevations above the sea up to a height of about 1600 feet. They freely cross transverse hills 100 feet in height, even when a little deflection would give them a course through a valley. None surmount hills of over 200 feet. No instance is known where a kame, after entering a valley bordered by hills more than 200 feet high, has left it, however crooked the valley may be. The only surface features which seem to invariably determine the location of eskers are drainage basins and hills more than about 200 feet high, measured on the north. In many instances eskers cross the beds of lakes, sometimes for many miles, and can be traced under water.

The observations of the author on the transport of the material of the eskers are so important that I give the following extract in full:—"With the exception of one short outcrop of granite the course of system IX. lies wholly within a region of slates, conglomerates, and limestones, for nearly 100 miles. It then crosses the granitic range of mountains extending north-eastward from Mount Desert. For seven miles after entering the granite area in Aurora the kame is composed almost wholly of slate, although the country on both sides is covered by granitic till, and shows multitudes of granite boulders and fragments. The granite then begins to appear in the kame, and, a few miles farther south-eastward, the kame plains are almost wholly composed of granite, although the underlying rock is there a micaceous slate or schist, and the till shows that kind of rock freely. These and other facts of similar import show that the kame materials have been

* *Rep. Geol. Surv. Ohio*, vol. iii., p. 40, 1878.

† *The Kames or Eskers of Maine*, by George H. Stone.—Proc. Amer. Assoc. Adv. Sci., 1880 (1881), p. 510; and *On the Kames of Maine*.—Proc. Boston Soc. Nat. Hist., 1880 (1881), p. 430.

transported lengthwise of the kames, and in general farther than morainal material originally derived from the same locality. In other words, kame drift is glacial drift plus a variable amount of water drift." The proof which the foregoing extract affords of the transport of material composing the esker, in a direction corresponding to its length and to its downward slope to the south, is confirmed by the observation that the gravel is less rounded and waterworn in the eskers near their origin on the north than farther south, and further by the prevailing direction of the dip of the stratification of the esker material, as well as by the expansion of many of the eskers into broad kame plains, as they approach their southern termination.

In their meandering, branching, looping, and other characters, the eskers of Maine precisely resemble those of this country; but they are of much greater length, sometimes extending for a distance of 150 miles.

The following extract will complete our account of this admirable memoir:—

"During the Champlain Period, the sea probably stood in the central parts of Maine at a height of 300 or 400 feet above its present level, and many kames were submerged during that period. The sides of a kame that has not been under the sea usually slope at the angle of stability of loose materials in air; while those that have been submerged have the form of low rounded bars, whose sides slope at the angle of stability of such materials in water. The fossiliferous Champlain Clays have hundreds of times been seen overlying the kames, and I have taken Mya, Balanus, and shells of other marine genera from the undisturbed clay found in the depression in a kame. The difference, in the physiognomy and structure of the kame which has been under the sea and that which has not, is so great as to show conclusively that the kames proper cannot have been of marine origin."—(Proc. Amer. Soc. Adv. Sci., *loc. cit.*, p. 518).

"Again, the kames bear the same relation to drainage basins as ordinary streams. At their northern ends, all, so far as known, originate in places favourable for collecting a considerable body of water from the melting glacier. That the flow of water was swifter in some parts of the streams than in others is shown by the nature of the deposits. Short slopes do not seem to have much affected the rate of flow, but on up-slopes or levels of several miles in length, the kames are usually large and of fine material, while on long down-slopes, or near the height of the higher divides, or in the jaws of narrow passes, they may wholly disappear, or be represented by the larger pebbles only. Every long kame-system in the State shows this alternation of finer and coarser material varying according to the slope. The map shows how often the kames disregard the lines of natural drainage. From this it may be inferred that these rivers were contained within ice walls, and that the ice surface was far from agreeing with the underlying land surface. That these rivers, for the most part, flowed in superficial channels in the ice is a fair

inference from the facts observed. Thus far but few signs of sub-glacial streams have been recognised far back from the coast. Near the coast there are some evident signs of such streams, and some kames may have been deposited by them." —(*Ibid.*, p. 516).

A study of the eskers of Connecticut Valley by Professor Dana* led him to doubt whether they were genuine eskers, and to contend that they are merely coarser parts of a system of alluvial terraces.

A theory, which has at least the merit of novelty, was proposed by Professor Shaler in 1884.† It will be readily understood from the following short citation :— "This association of kames with drift deposits formed beneath the surface of water, long ago led me to the hypothesis that the ordinary kames are structures that were made beneath the surface of water-covered regions, and that they accumulated at the points where subglacial rivers discharged their streams beneath the ice into the sea, or the temporary lakes that abounded over the land-surface during the glacial period." Subsequent investigation has, however, led him to relinquish this explanation.

An interesting Paper was read before the British Association in 1884 by Professor Carvill Lewis.‡ It contains a general account of eskers, of the literature of the subject, and of proposed explanations. The author agrees that either they "must have been enclosed within high walls of ice, or the streams of water which formed them must have flowed in subglacial tunnels." The direct object of the paper is the description of certain eskers in Pennsylvania, which stand in close connection with the great terminal moraine, being sometimes continuous with it; they are all short, from a few hundred feet to a few miles in length, and they slope downwards towards a river valley, or other watercourse, in the opposite direction to the movement of the once overlying ice. Professor Lewis consequently concludes that they were formed by a backward sub-glacial drainage.

Professor Winchell,§ after describing an important esker, which he names the Bridgewater kame, gives a long series of important conclusions which he thinks may be drawn from it. Briefly summarised, these are that the esker was formed by an existing river, "Straight River," at a time when its waters flowed over the upper surface of a glacier.

Kames are described as occurring in Canada by Mr. R. W. Ells and Mr. R. Chalmers.‖ Both of these observers call attention to the resemblance in the course

* *The Kames of Connecticut Valley*, by J. D. Dana.—Amer. Journ. Sci., vol. xxii., 1881 (1882).

† *On the Origin of Kames*, by N. S. Shaler.—Proc. Boston Soc. Nat. Hist., vol. xxiii., p. 36, 1884.

‡ *On Marginal Kames*, by H. Carvill Lewis.—Proc. Acad. Nat. Sci. Philadelphia, 1885, p. 157.

§ *The Geology of Minnesota*.—Final Report, vol. i., 1884, p. 665.

‖ *Geol. Survey of Canada*, 1885, p. 65 E. and 28 GG.

of the eskers to a winding river; the esker described by Mr. Ells runs along with the Hebert River, which is considered to have had some share in its formation. Mr. Chalmers attributes the kames observed by him to post-glacial streams.

There is a short reference to eskers by Professor Shaler in 1889*; it is chiefly interesting for its virtual retractation of his earlier views, and the statement that he regards eskers as formed within sub-glacial channels during the last stages of the melting of the ice-sheet.

Numerous eskers and kames are described by Mr. Warren Upham in different parts of Minnesota,† and referred to the action of streams flowing through cañons in the ice.

A very welcome addition was made to our knowledge in 1890 by Professor G. F. Wright in his work on *The Ice Age in North America* (Kegan Paul & Co., London), containing (p. 62) a description of eskers actually in process of formation. It runs as follows:—

"Now that the front is retreating, this sub-glacial stream occupies a long tunnel, twenty-five or thirty feet high, in a stratum of ice which is overlaid to a depth, in some places, of fifteen or twenty feet with waterworn glacial *débris*. In numerous places the roof of this tunnel has broken in, so that the overlying *débris* is caving down into it. In places the tunnel is deserted by the stream, and the accumulating *débris* thus forms a tortuous ridge, with projecting knolls where the tunnels are oldest and largest. At the same time the ice on the sides at some distance from the tunnel, where the superficial *débris* was thinner, has melted down much below the level of that which was protected by the thicker deposit; and so the *débris* is sliding down the sides as well as into the tunnel through the centre. Thus three ridges, approximately parallel, are simultaneously forming, one in the middle of the tunnel, and one on each side. When the ice has fully melted away, this *débris* will present all the complication of interlacing ridges, with numerous kettle-holes and knobs characterising the kames; and these will be approximately parallel with the line of glacial motion." Again (p. 300):—"Of course these glacial streams must, in the main, have followed the great valleys; but many of the minor valleys were, at that time, so obstructed that the streams might disregard them and take a more direct route over the ice through the open channels and long tunnels which must have existed. Those familiar only with the contracted glaciers of the Alps are scarcely prepared to appreciate the extent to which currents of water flow over the larger glacial masses and rearrange and transport the superficial material collected on them. The 'sub-glacial' streams also are not always strictly sub-glacial; since they often flow through tunnels which are midway between the top and the bottom of the ice-mass. In the Muir

* Ninth Annual Report Geol. Survey, United States, 1887, 1888, 1889, p. 550.

† *Geology of Minnesota*, Final Report, vol. ii., 1888.

glacier, Alaska, for example, the two streams issuing from the ice-front near the sides of the glacier are several hundred feet above the level at which the two streams emerge near the centre of the channel. There, also, streams of water of more or less size, can occasionally be seen pouring out from the perpendicular front of the ice a hundred feet or more above the surface of the inlet. Nor is it any uncommon thing to see icebergs move off with water-worn tunnels in them which are still well filled with gravel and pebbles. In the various depressions in the surface of the glacier also, where, at times, extensive lakes of water are formed, there is much accumulation and assortment of earthy material far back from the terminal margin of the glacier."

Another important contribution to our knowledge of melting glaciers is furnished by Mr. Russell in his account of the Malaspina glacier of Alaska.* This glacier the author regards as the type of a hitherto not fully recognised class, which he terms "*piedmont* glaciers," because they form at the foot of mountains, by the union and expansion of tributary mountain glaciers. The Malaspina glacier extends continuously from Yakutat Bay for seventy miles westward, and has an average breadth of twenty-five miles. It is a vast, nearly horizontal plateau of ice, having, at a distance of five or six miles from its outer border, an elevation of about 1500 feet. After giving an account of the drainage of the glacier, the author adds:—

"The drainage of the Malaspina glacier has not been investigated as fully as its importance demands; but the observations already made seem to warrant certain conclusions in reference to deposits made within the glacier by subglacial or englacial streams. When the streams from the north reach the Malaspina glacier they invariably flow in tunnels and disappear from view. The entrances to these tunnels are frequently high arches, and the streams flowing into them carry along great quantities of gravel and sand. . . . About the southern and eastern borders of the glacier, where the streams emerge, the arches of the tunnels are low, owing to the accumulation of *débris* which obstructs their discharge. In some instances, as at the head of Fountain stream, the accumulation of *débris* is so great that the water rises through a vertical shaft in order to reach the surface, and rushes upwards under great pressure. . . . The streams flowing from the glacier bring out large quantities of well-rounded sand and gravel, much of which is immediately deposited in alluvial cones. This much of the work of subglacial streams is open to view, and enables one to infer as to what takes place within the tunnels.

"The streams issuing from the ice are ever loaded with detritus, and, besides, on emerging, frequently receive large quantities of coarse *débris* from the adjacent

* *Second Expedition to Mount St. Elias in* 1891, by I. C. Russell.—13th Ann. Rep. U. S. Geol. Survey, 1893; and on *The Malaspina Glacier*, The Journal of Geology, vol. i., 1893, p. 219.

moraine-covered ice-cliffs. The streams at once deposit the coarser portion of this, thus building up their channels and obstructing the outlets of the tunnels. The blocking up of the tunnels must cause the subglacial streams to lose force, and deposit sand and gravel on the bottom of the channels; this causes the water to flow at higher levels, and coming in contact with the roofs of the tunnels, enlarges them upwards; this, in turn, gives room for additional deposits within the ice, as the alluvial cones at the extremities of the tunnels grow in height. In this way narrow ridges of gravel and sand, having perhaps some stratification due to periodic changes in the volume of the streams, owing to seasonal changes, may be formed within the ice. When the glacier melts, the gravel ridge contained within it will be exposed at the surface, and as the supporting walls melt away, the gravel at the top of the ridge will tend to slide down, so as to give to the deposit a pseudo-anticlinal structure. Ridges of gravel deposited in tunnels beneath the moraine-covered portion of the Malaspina glacier would have boulders dropped upon them as the ice melts; but where the glacier is free from surface *débris* there would be no angular material left upon the ridges when the ice finally disappeared."

Such is the author's explanation of the formation of eskers. He adds:—"The process of subglacial deposition pertains especially to stagnant glaciers of the Malaspina type, which are wasting away. In an advancing glacier it is evident that the conditions would be different, and subglacial erosion might take the place of subglacial deposition."

Warren Upham briefly recurs to the subject of eskers in discussing the "*Criteria of Englacial and Subglacial Drift*,"* and maintains his previously expressed views in favour of the deposition of eskers within ice-cañons.

In an interesting account of the sand-plains, eskers, and kames of the Auburndale district, ten miles east of Boston, Mr. W. M. Davis† shows how these different features are genetically connected, and attributes the eskers to subglacial streams, without denying that in other districts they may have a superglacial origin.

Mr. Warren Upham‡ supports the view that much of the glacial drift was carried within the substance of the ice, and cites Bird's Hill esker, near Winnipeg, as proving that englacial drift had been carried up from a nearly level country to a height of more than 500 feet in the ice-sheet.

Professor Salisbury§ describes eskers which have been mapped by Professor Culver. They are ascribed to streams flowing from the ice-sheet.

* The American Geologist, vol. viii., 1891, p. 380.

† *The Subglacial Origin of Certain Eskers*, by W. M. Davis.—Proc. Boston Soc. Nat. Hist., vol. xxv., p. 477, 1890–1892.

‡ *On Englacial Drift*, by Warren Upham: The American Geologist, vol. xii., p. 36, 1893.

§ *Ann. Report Geol. Survey, N. J., Trenton*, 1893.

Mr. W. O. Crosby* writes of eskers as formed by sub- and super-glacial streams; but subsequently speaks of superglacial rivers alone. Thus he says:—"The glacial streams had undoubtedly, in many cases, deeply grooved and divided the marginal portion of the ice, and in these grooves or channels was accumulated, after the manner of rivers, the narrow deposits of sand and gravel, which, when the ice melted away, became the steep winding ridges which we call kames and eskers. At the mouths of these glacial rivers, delta-plains were formed in the lakes, adjacent deltas often becoming confluent. The plains are thus naturally coincident in height with the eskers and often appear as expansions of the latter."

The subglacial origin of eskers is again asserted by Mr. Stone,† in an interesting, but highly theoretical, Paper, in which he calls attention to the fact that, in the State of Maine, along 200 miles of coast, the eskers decrease in size as they proceed towards the sea; at the same time becoming increasingly discontinuous, until they terminate near the heads of fjords, without extending beneath the sea. Mr. Stone thinks an explanation may be found in the glacial submergence, which prevented the subglacial tunnels in that part of the ice which entered the sea from enlarging with the same rapidity that they did elsewhere; the result being that the subglacial rivers, being confined within narrower channels, flowed with such velocity that detritus was swept away and deposition rendered impossible.‡

Mr. Stone's Paper is followed by a very important contribution from Professor Chamberlin,§ who shows that drumlins are essentially of subglacial origin, and that kames are associated with them in such a manner as to prove that the gravel of the kames "is but a partially assorted derivative from the till of the region." A somewhat similar result is reached in the case of eskers.

A very instructive model showing the relations of sand-plains, eskers, and kames to each other, and to the stagnant glacier which is supposed to have produced them, are described by Mr. F. P. Gulliver.‖

A suggestive Paper, by Mr. J. B. Woodworth,¶ appeared in 1894. In discussing the variation of the crest-line of eskers in height above the surrounding country, the author suggests that this may be connected with changes in the breadth of the

* *Geology of the Boston Basin*, by W. O. Crosby: Occasional Papers of the Boston Soc. Nat. Hist. IV., vol. i., pp. 160 and 274, 1893 and 1894.

† *The Osar Gravels of the Coast of Maine*, by George H. Stone: Journ. Geology, Chicago, vol. i., p. 246, 1893.

‡ A review of this Paper appeared in the *American Geologist*, vol. xii., p. 122, criticising some of its conclusions. A reply by Mr. Stone follows in the same volume, p. 200.

§ *The Horizon of Drumlin, Osar and Kame Formation*, by T. C. Chamberlin: Journ. Geology, Chicago, vol. i., p. 255, 1893.

‖ Journ. Geology, Chicago, vol. i., p. 803, 1893.

¶ *Some Typical Eskers of Southern New England*, by J. B. Woodworth.—Proc. Boston Soc. Nat. Hist., vol. xxvi., 1894, p. 197.

ridge. For suppose the esker to have had originally a rectangular section, and to have acquired its existing form by the sliding down of materials, along its sides, then if the base of the rectangle is greater than the altitude, in any ratio greater than 3 to 2, the final height of the esker, after sliding, will be the same as the original height; but if the ratio be less than this, the final height will be less than the original height; thus in one and the same esker-ridge we should expect to find the broader portions higher than the narrower.

An attempt is then made to show that the variation in height is connected with changes in direction of the esker, and with associated changes in the width of the meandering ice channel in which it was formed. The author admits, however, that "many eskers do not display a consistent and regular variation in their lines."

In the abstract of my Paper,* on *A map of the Esker Systems of Ireland*, it is said that the esker may represent a "cast," as it were, of a glacier-tunnel in gravel and sand. On this hypothesis, all the known characters of eskers find an explanation, as well as many incidental details, such as the long lakelets, or shallow streams, by which they are not infrequently flanked. The details of the explanation are not given; but this defect is supplied by Mr. Woodworth, who, to my great satisfaction, has arrived at a view precisely similar to my own. I reproduce the diagram which

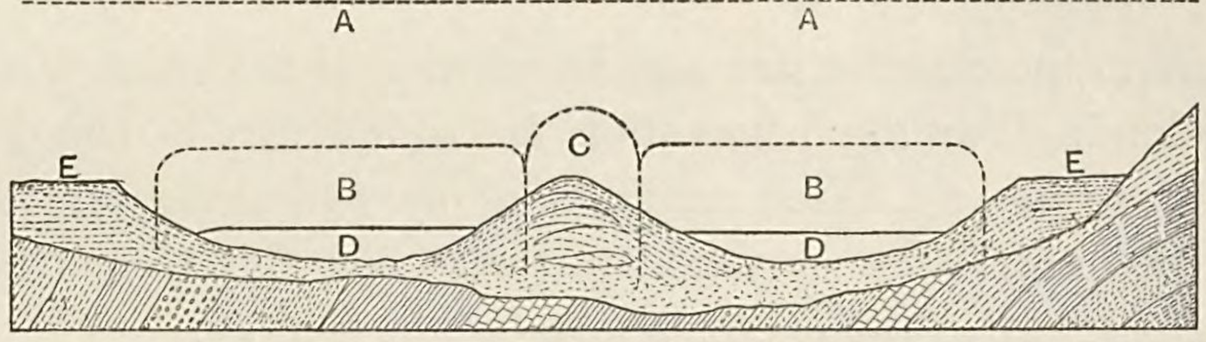


Fig. 1. (From Mr. Woodworth's Paper just referred to.)

Generalized section across meridional valley, with lateral moraine terraces (or hillside kames), with medial esker, showing symmetry due to deposition of sands and gravels in the presence of melting valley-tongues of the ice-sheet. AA, ice-sheet previous to the stage BB, when isolated blocks hold open cavities between the esker and the terraces, EE. C is the tunnel in AA in which the esker originates. DD, esker ponds or swamps.

he gives in illustration of this view. Dr. Hummel's explanation of the esker-moat has been given previously (*v. antea*, p. 791). On reviewing the preceding account—which is far from complete—it will be seen that ever since Hummel first attributed the peculiar features of eskers to the influence of once existing ice, geologists, familiar with these features, have, with almost one accord, expressed themselves in agreement with this explanation. Nor could it well have been otherwise. Some material must have existed to furnish a support to the sides of the eskers, during their formation; but this material has since completely disappeared; and the only substance at all likely to have behaved in this manner is ice.

* Rep. Brit. Ass. Adv. Sci., p. 777, 1893.

When from this general statement, we pass to matters of detail, unanimity is at an end, and geologists are found occupying two opposing camps, one represented by Hummel and the other by Holst, with intermediaries who agree with both. The one regards ground-moraine as the source of the material of the esker, the other prefers to derive it from superglacial or englacial drift; the one pictures its deposition in subglacial tunnels, the other in ice cañons.

Much time has been spent in speculative discussion of these points—time not wholly wasted, since the imagination having produced many pictures of what might have occurred, observation has been assisted in its task of more speedily recognising, in the field, those phenomena which are serviceable for explanation. The only observations which we possess, directly bearing on the question, are those of Wright and Russell; and these agree in referring the place of deposition of eskers to tunnels in the ice, not necessarily at its base, and in attributing their material, at all events to a large extent, to superficial moraine matter. So far as observation helps us, it finds truth in the views of both Hummel and Holst; though in both, likewise, some error. The glaciers described by Wright and Russell, though dwindling, are not in the final stages of dissolution; and thus many important problems connected with the formation of eskers still wait for solution: such, in particular, as the remarkable manner in which they run up and down over hills 100 to 200 feet in height.

We now pass to the classification and description of the chief systems of eskers met with in Ireland. For the information on which this is based I am almost wholly indebted to the published writings of my colleagues on the Geological Survey; and the information on the map, also, which this account is intended to explain, is abstracted from the one-inch maps of the Survey.

The System of Ballyhaunis.

This system consists of five principal chains, with several outlying mounds and ridges distributed over the eastern part of county Galway, the west of county Roscommon, and the south of county Mayo. Enumerated in the order in which they are encountered, on proceeding from north and west to south and east, these chains may be named as follows:—

1. Ballindine chain, with an outlying group of ridges, north of Claremorris, in county Mayo.
2. Dunmore chain.
3. Tuam chain.
4. Kilnalag chain.
5. Moyne chain.
6. Newtown-Bellew chain. (All in fig. 2.)

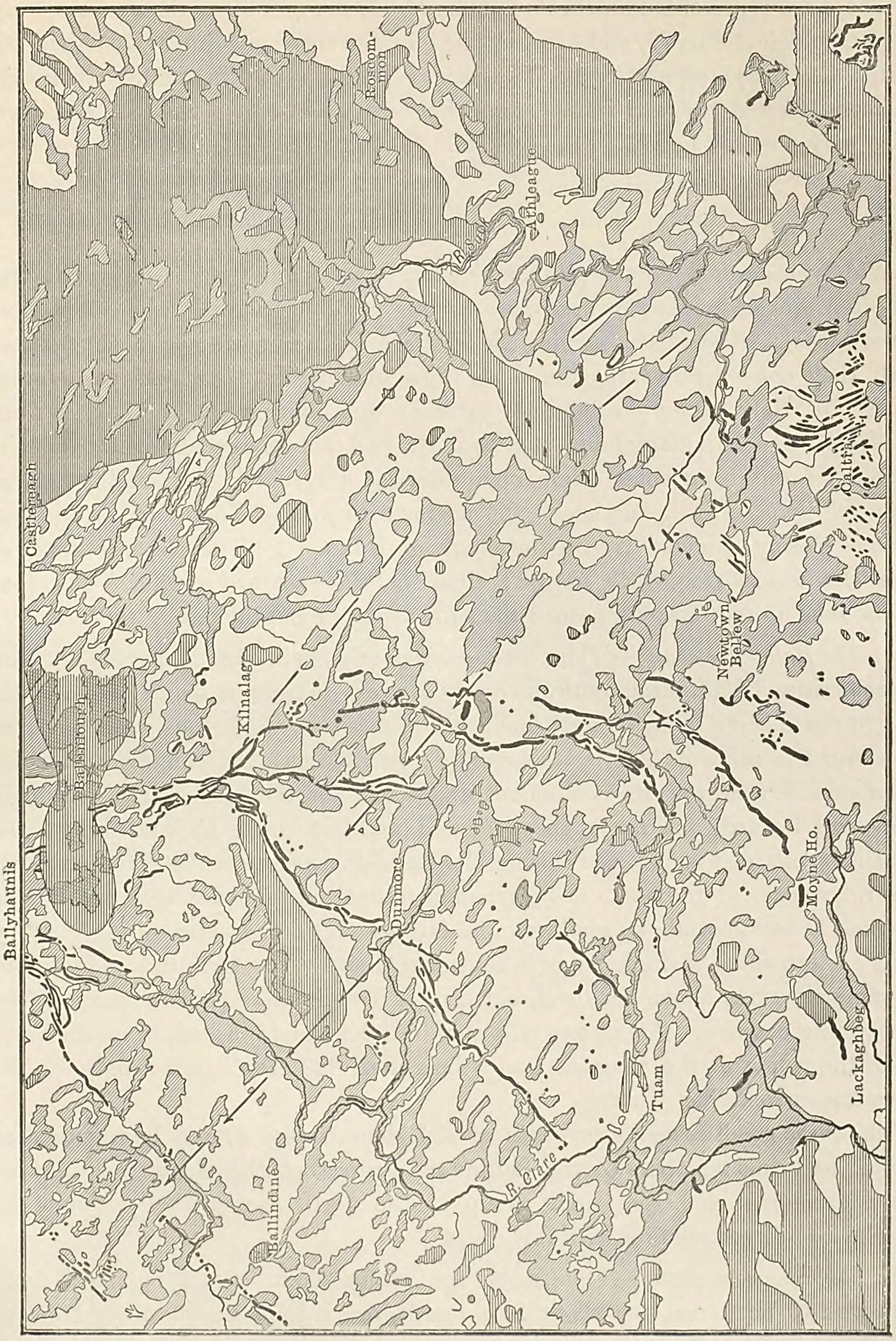

Roscommon
R. Suck
Athleague
Castlereagh
Kilnalag
Ballyhaunis
Ballintober
Dunmore
Newtown Bellew
Moyne Ho.
Tuam
Lackaghbeg
R. Clare
Ballindine
Scale 0 5 10 15 20 Miles

FIG. 2.

These are represented on sheets numbered 76, 86, and 96 of the one-inch map of the Geological Survey, and are described in the corresponding "Memoirs," by Messrs. R. G. Symes, and S. B. Wilkinson. To the south, in southern Galway, on sheets 105 and 106, are fragmentary chains, described by Mr. G. H. Kinahan, which may possibly belong to this system. The more important are:—

7. Kilcornan chain.
8. Athenry chain.
9. Monivea chain.
10. Gortachalla chain.

Widely separated on the south and west, these chains pursue an undulating and often broken course; at first more or less parallel, trending from south-west to north-east; afterwards, turning more towards the north, or even west of north, they converge towards the small town of Kilkelly, county Mayo, 9 miles N.N.W. of Ballyhaunis; sometimes meeting and uniting on the way. Thus the Moyne and Kilnalag chains (fig. 2) unite just before reaching the hamlet of Kilnalag, forming an acute angle open towards the south; the single chain so produced joins, a little further to the north, with that of Tuam, which, in turn, becomes closely associated with the chain of Dunmore. The western slopes of these chains are frequently abrupt; those on the east are gentler. The four chains, thus united, may be termed the sub-system of Ballinlough.

1. *The Ballindine chain.*—This, the most westerly chain (fig. 2), begins between Claremorris and Ballindine, both in county Mayo; its trend is mainly from south-west to north-east; and, though much interrupted by numerous gaps, some of them over two miles in length, it is clearly traceable past Ballyhaunis, and as far as one mile beyond it. Its component eskers lie, for the most part, in a single series, but towards the north they form a multiple series by branching; the branches sometimes re-unite, enclosing elongated depressions. The three northern-most ridges pass, on the north of Ballyhaunis, into a flat-topped mound, the surface of which is 340 feet above sea-level, and 80 feet above the surrounding country on its eastern side; a single ridge is continued northwards from this mound with the same elevation above sea-level, but with a height of only 60 feet above the surrounding country. About one mile south of the mound, as shown on the map, one of the ridges of the chain attains a height of 363 feet, but it is only 43 feet above the surrounding country.

The three small eskers, seen south of Ballyhaunis (fig. 2) may be regarded as parallel outlying members of the Ballindine chain; but the cluster on the west near Claremorris, and the small group to the north near Kilkelly, cannot be brought into direct relation with this chain.

2. *The Dunmore chain.*—This fairly continuous chain (fig. 2) extends from south-west to north-east for about 14 miles before it joins the *plexus* or knot, of Ballinlough. Though a single series for the most part, it is in some places

accompanied by one or more parallel ridges, and about one mile from its confluence with the eastern chains it becomes a *plexus*, formed by the union of four approximately parallel ridges. It is difficult to estimate its height, on account of the undulating nature of the surrounding country, which is sometimes higher on one side of an esker than on the other; from 30 to 60 feet is a sufficiently close approximation. The following Table shows how the chain rises in passing from south to north, the ground rising with it:—

Miles from Origin.	Height above Sea-level (in feet).	Height of Country above do. (in feet).	Esker's own Height (in feet).
2·00	245	204	41
3·60	243	207	36
6·50	273	239	34
8·50	281	W. 217, E. 234	55 or 56
13·25	327	—	—

North of Dunmore, up to its confluence with the eastern chains, the chain lies in a broad, gentle depression; the ground on each side rising gradually to a height of between 400 or 500 feet above the sea.

3. *The Tuam chain.*—This (fig. 2) is of about the same length as the Dunmore chain, but it is interrupted in the middle by a wide gap about $5\frac{1}{2}$ miles long. It southern moiety runs at first from west to east, but soon turns into the south-west to north-east direction, taken by the corresponding parts of the more continuous chains; the northern moiety runs due north. The following Table shows that this chain, like the preceding, rises as it proceeds north; the country rising with it in the same direction:—

Miles from Origin.	Height above Sea-level (in feet).	Height of Country above do. (in feet).	Esker's own Height (in ft.)
1·00	297	245	52
2·25	322	286	36
4·60	338	303	35

The country between the Dunmore and Tuam chains is richly dotted over with conical gravel mounds.

4. *The Kilnalag chain.*—This chain (fig. 2), which is not quite 14 miles in length, runs at first from south-west to north-east, and then turns due north, which direction it maintains for the greater part of its course. At Ballyphilipeen,

about 3 miles from its origin, it receives a tributary which arises close to the Moyne chain on the east, and immediately south of Kilnalag, where it enters Loughapollboy bog, it is definitely joined by the Moyne chain. Past Kilnalag it becomes a double chain enclosing an elongated depression, and then unites with the Tuam chain.

The next Table shows the changes which this esker chain undergoes in elevation above the sea, and in its own height, as we proceed along it northwards :—

Miles from Origin.	Height above Sea-level (in feet).	Height of Country above do. (in feet).	Esker's own Height (in ft.)
2·00	293	260	33
2·75	312	286	26
5·00	321	276	45
8·00	333	292	41
8·50	327	296	31
11·75	350	311	39
13·00	346	298	48

5.—*The Moyne chain.*—It is difficult to determine the commencement of this chain (fig. 2) on the south. It may begin with the isolated esker near Ballynapark, or possibly with that of Lackaghbeg, 5 miles further to the south-west; a gap about 3 miles long separates the Ballynapark esker from another isolated ridge, running from west to east, on which Moyne House stands; and another gap of about one mile intervenes between this and the main part of the chain, which runs for the next 8 miles of its course almost continuously; and though it retains at first, and for a short distance, the west to east direction of the more broken ridges, it soon turns towards the north-east, and finally due north. For the last 7 miles of its course the chain is very much interrupted, the gaps being much longer than the ridges. On reference to the map it will be seen that the height of this chain, also, above sea-level, increases as we follow it from south to north. (*Mem.*—In fig. 2, "Lackaghbeg" should be "Ballynapark." Lackaghbeg lies a little outside the southern boundary of this map.)

6. *The Newtown-Bellew chain.*—Where the Moyne chain bends round from a north-eastward to a due northward direction, it receives a tributary (fig. 2) which may have been fed by the same streams that deposited three parallel eskers, which lie not far from it on the S.E., and which trend from S.S.W. to N.N.E.

Still further to the south many scattered eskers occur, some of which may be brought into connection with these just mentioned. They are difficult to classify, but may be tentatively arranged as follows :—

7. *The Kilcornan chain.*—Near the mouth of the Clarin river, which opens into Galway bay, is a single chain of eskers which runs towards the north-east up the Clarin valley, past Kilcornan, towards Greethill. This may possibly have belonged to the same system of drainage as that of the chains already described, further to the north; but in the absence of evidence it is impossible to speak more definitely.

8. *The Athenry chain.*—This consists of two branches, the Greethill and the Loughan chains, which unite about one mile north-east of Athenry. The Loughan chain is a complicated group of parallel ridges receiving short tributaries.

9. *The Monivea chain.*—West and north of Athenry a much interrupted and multiple chain runs from the south-west towards Menlough, on the north-east, receiving south of Monivea a west-to-east tributary, the Knockbrack chain. On the west of Menlough a more or less parallel chain runs from Ryehill past Carbally Castle.

In addition to the foregoing, several isolated groups of eskers are to be seen in this district, as for instance those of Cloghmoyle Castle and of Pollsillagh.

10. *The Gortachalla chain.*—About 11 miles north-west of Galway town, on the west of Lough Corrib, a chain of eskers, about $4\frac{1}{2}$ miles in length, runs almost due east, passing north of Gortachalla Lough. There is a bare possibility that this may belong to the Ballyhaunis system.

The System of the Midlands.

This great and complicated system may be divided into four subordinate systems; these are:—

I. System of Clara. III. System of Edenderry.
II. ,, Parsonstown. IV. ,, Trim.

I. THE SYSTEM OF CLARA.—This consists of several subsidiary and three main chains, which run from west to east, converging eastwards, to unite near Judgeville, about 10 miles east of Clara. They are shown in detail on sheets 97, 98, 99, 107, 108, 109 of the one-inch map of the Geological Survey, and are described in the corresponding Memoirs by Messrs. J. O'Kelly, F. J. Foot, G. H. Kinahan, and R. G. Symes.

Beginning on the north, and proceeding southwards, these chains are as follows:—

i. Chain of Newtown-Loe (5 miles south-west of Lough Ennell).
ii. ,, Seven Churches (Clonmacnois).
iii. ,, Ballyduff (passing about $1\frac{1}{2}$ miles north of Tullamore).

i. *The Newtown-Loe chain.*—This includes the following chains:—

1. Newtown-Loe chain proper and the tributary chain of Ballynagore (about 5 miles south-west of Lough Ennell).
2. Streamstown chain (the southern part of which is nearly 6 miles west of Lough Ennell).
3. Ballymore chain (about 9 miles west of Lough Ennell), and the parallel chain of Ballymahon (about 12 miles west of Lough Ennell).
4. Athlone chain, with several tributaries, including that of Lough Funshinagh.

1. *The Newtown-Loe chain proper.*—This commences in the bog of Donore Bridge, with a direction from north-west to south-east; but, after a straight course of about a mile and a half, it turns at first east, and then south-east, forming a wide convex curve open to the south, and then enters the main system of Clara.

About the middle of the curve the small chain of Ballinagore, coming from the north, is brought into close proximity with it; and with this the eskers west of Lough Owel and Lough Ennell should probably be associated. Where its course is most eastward a single long esker runs parallel at no great distance from it, the intervening ground being occupied by bog.

The height of the chain is given as about 70 feet, the angle of the slope on each side as 30°. Large blocks of limestone rest upon its flanks.

2. *The Streamstown chain.*—This complicated chain, nearly 12 miles long altogether, running, on the whole, north and south, may represent a northern feeder of the Newtown-Loe chain. About Streamstown it forms a *plexus*, of which fig. 3, taken from the Survey Memoir, gives a good representation.

3. *The Ballymore chain.*—This broken chain extends southwards, roughly parallel to the southern part of the Streamstown chain, and about $3\frac{1}{2}$ miles to the west of it. About 6 miles south of Ballymore it turns sharply south-eastwards; $1\frac{1}{2}$ miles further on in that direction we come to an isolated esker with the same direction, and therefore parallel to that portion of the Newtown-Loe chain already mentioned as running north-west to south-east, the distance between them being 2 miles. This may possibly represent the southerly termination of the Ballymahon chain.

The N.N.W. to S.S.E. chain, lying about 2 miles west of that of Ballymore, is the Ballymahon chain.

4. *The Athlone chain.*—This is a very fragmentary and complicated chain. Starting from the west among the confused group of eskers east of Killeglan (fig. 4), it runs in a very irregular way, with a generally easterly trend; north

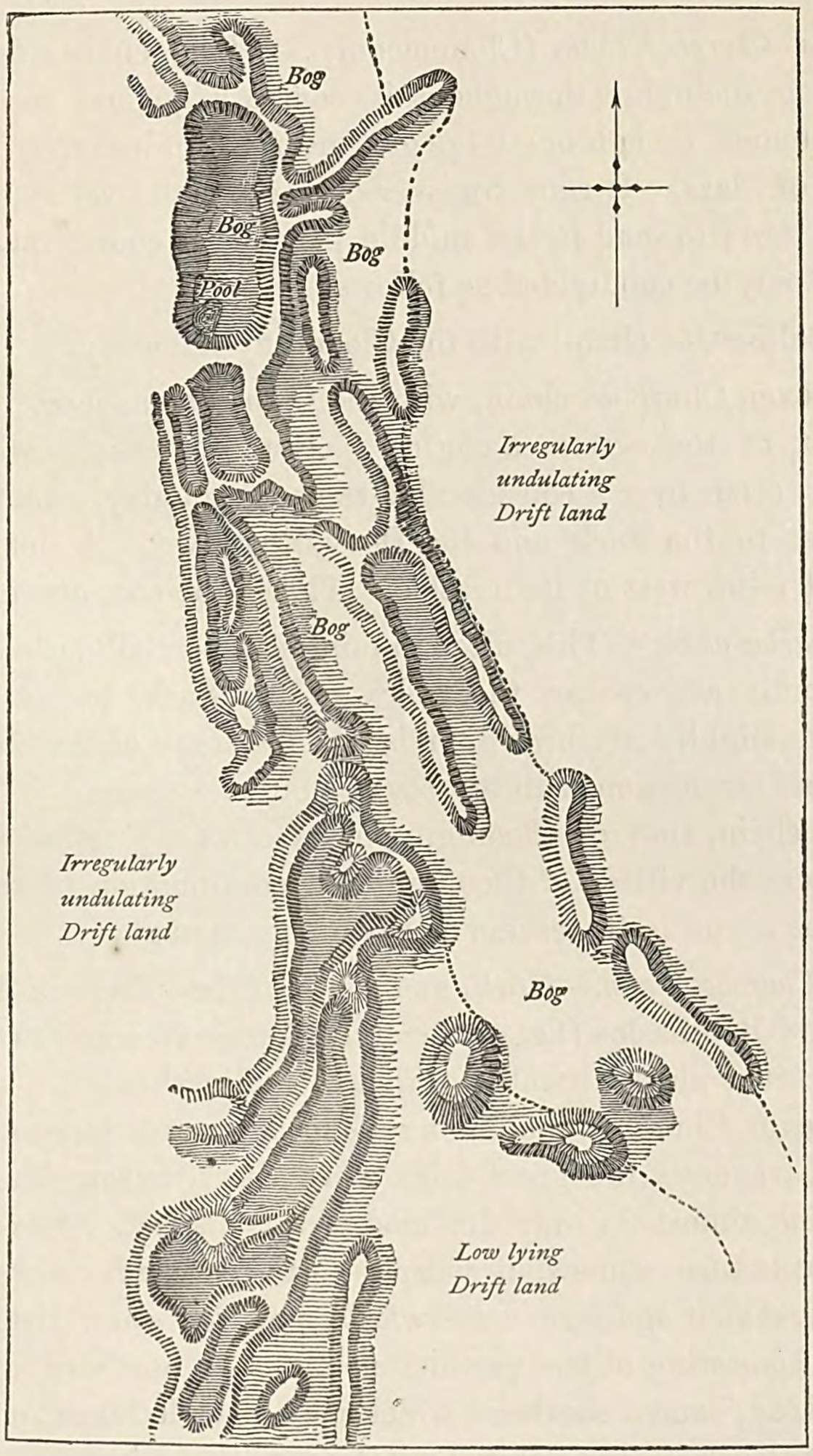


Fig. 3.

of Moate (fig. 4), however, it takes an E.S.E. direction, and finally trends again to the east; thus repeating the behaviour of the two preceding chains. Several tributary chains from the north enter or approach it near its western extremity, one of the largest of these being that which commences near Lough Funshinagh.

A railway-cutting, east of the town of Moydrum, affords a good section through one of the eskers of this chain; beds of gravel and sand with seams of hard clay are exposed; oblique lamination is common, and the beds are curved, contorted, and faulted.

ii. *The Seven Churches chain* (Clonmacnois). — This chain (fig. 4), which is over 43 miles long, maintains throughout its course a general west-to-east trend. It is fairly continuous, though one large gap, nearly 4 miles long, breaks through it $2\frac{1}{2}$ miles west of Clara. It runs transversely across the valley of the Shannon, and thus lies on lower ground in the middle part of its course than at either end. The main chain may be subdivided as follows:—

1. Ballinasloe chain, with the Cloonigny tributary.
2. Seven Churches chain, with the Clonmacnois loop.

On the west of the system a confused cluster of eskers, which cannot be reduced to order, occur over a considerable tract of country, about the watershed of the tributaries to the Suck and the Dooyertha river. A definite chain first appears about $6\frac{1}{2}$ miles west of Ballinasloe. This is the commencement of—

1. *The Ballinasloe chain.*—This, after running east to Ballinasloe (fig. 4), curves gently to the south-east, crosses the valley of the Suck, passes near Oldtown, and then, curving slightly northward, ends in the callows of the Shannon without coming into direct connection with the Seven Churches chain.

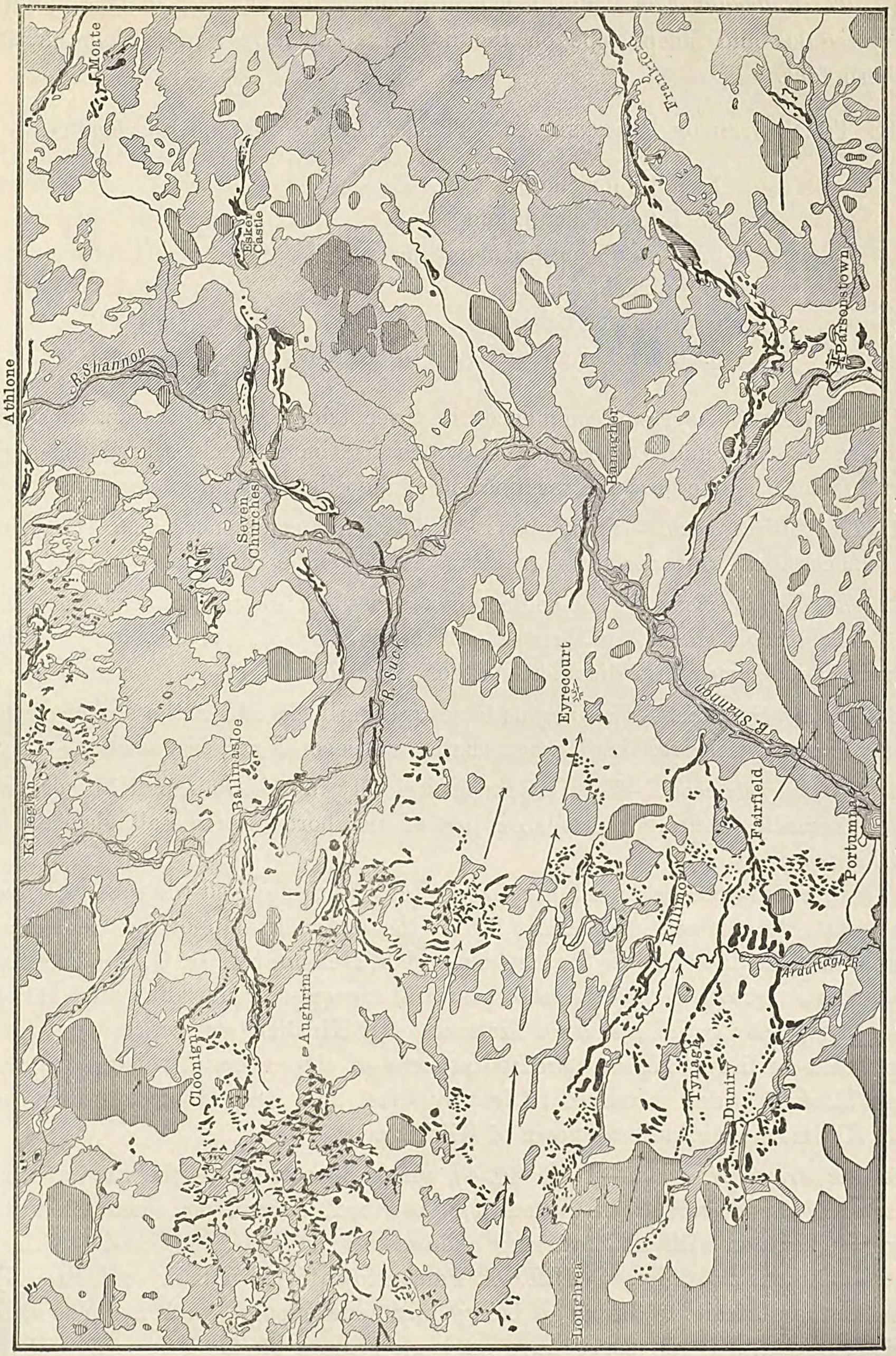
A tributary chain, that of Cloonigny, rises some $5\frac{1}{2}$ miles west by north of Ballinasloe, near the village of Cloonigny; a continuation of this on the west and north may be found in the eskers of Doon and Annagh.

2. *The Seven Churches chain.*—North and south of the village of Aughrim, about 5 miles W.S.W. of Ballinasloe (fig. 4), several eskers converge towards a west-to-east chain, which runs almost parallel to that of Ballinasloe.

This is the Seven Churches chain; it runs for a great distance almost due east, crosses the Suck, traverses the great bogs which lie between this river and the Shannon, affording almost the only dry land of this district, crosses the Shannon, and soon afterwards turns somewhat sharply north-eastwards to Seven Churches. From Seven Churches it again runs eastwards, and for some distance the chain becomes double, consisting of two parallel members—a northern, over which runs "The Pilgrim's Road," and a southern, which may be called the Clonmacnois loop.

It is a remarkable fact, first pointed out by Mr. F. J. Foot, that the breach in the Seven Churches chain, through which the river Shannon flows, is only just large enough for the passage of this river; attention is called by Mr. J. O'Kelly to a similar feature in the Newtown-Loe chain, where the river Brosna passes through it, and again in the Ballyduff chain, where this is traversed by the Silver river.

FIG. 4.


Athlone
Monte
Esker Castle
R. Shannon
Seven Churches
R. Suck
Ballinasloe
Killeglan
Cloonigny
Aughrim
Eyrecourt
Ballinahinch
Parsonstown
R. Shannon
Killimor
Tynagh
Dunkry
Fairfield
Portumna
Ardattagh R.
Loughrea
Scale 0 5 10 15 20 Miles

iii. *The Ballyduff chain.*—This is a continuous esker, 11 miles in length, with a very regular and steep slope on the northern and a very gentle one on the southern face.

II. THE SYSTEM OF PARSONSTOWN.—This consists of the following chains :—

1. Killimor chain.
2. Tynagh chain, and
3. Duniry chain, converging into
4. Fairfield chain.
5. Frankford chain.
6. Banagher chain. (All in fig. 4.)

On the west the system commences in three tributary chains, viz. those of Killimor, Tynagh, and Duniry (fig. 4), which rise immediately east of the high ground formed by the northern termination of the Slieve Aughta mountains.

1. *The Killimor chain.*—This, about 7 miles long, commences near Dartfield, and runs eastward to its termination in the callows of the Shannon.

2. *The Tynagh chain.*—This begins in a series of isolated hillocks, not far from Masonbrook House, and runs past the village of Tynagh, to join the Duniry chain, some little distance west of Fairfield.

3. *The Duniry chain.*—This begins in separate hillocks about the source of the Duniry river ; it receives the Tynagh chain, and is continued eastward as—

4. *The Fairfield chain.*—This approaches closely to the chain of Killimor, but without actually reaching it, and ends just on the borders of the alluvial flats of the Shannon.

The preceding chains, which may be collectively designated the sub-system of Portumna, are represented on sheet 116 of the one-inch map of the Geological Survey, and are described in the accompanying Memoir by Mr. G. H. Kinahan. They present us with one of the most beautiful examples of river-like distribution to be found among the eskers of Ireland. Mr. Kinahan states that numerous large blocks of limestone are perched on some of the eskers of this group; the largest block recorded measured 12 feet by 9 feet by 4 feet. It lies on the slope of the Killimor chain, near the town of Killimor.

5. *The Frankford chain.*—This (fig. 4), which appears to be the natural continuation of the Portumna sub-system just described, is, however, separated from it by the Shannon with its bordering callows. It is fairly continuous, with a length of about 25 miles. N.N.E. of Parsonstown it is narrow and strongly marked, the summit of the ridge being only wide enough, in some places, to admit of a roadway; its slopes have an angle of from 30 to 35 degrees, and its

height varies from 35 to 50 feet. It terminates between two and three miles south-west of Tullamore.

I had the advantage of studying this esker under the guidance of Lord Rosse, who pointed out to me numerous boulders and pebbles of Galway granite amongst the rubbly material of which it consists in great part. Lord Rosse also showed me specimens of Connemara marble which he had collected from the esker.

South of Parsonstown are several eskers, trending from west to east, which, with that near Muddy Lough, more to the east, may be doubtfully associated with the Frankford chain.

6. *The Banagher chain.*—This not very well-marked esker (fig. 4), which occurs a few miles north of the Frankford chain, begins a little more than two miles to the east of Eyrecourt, and runs due east, ending against the Shannon.

III. The System of Edenderry.—The only important chain of this group is that of Philipstown; it lies south of Edenderry, and begins east of Philipstown as a low ridge, 13 feet in height, but rises eastward until it attains a height of 59 feet, and is then 286 feet above the sea-level; it sinks further on to a height of 25 or 30 feet, and after a course of $3\frac{1}{2}$ miles in all, disappears in a bog. It recommences further to the east, forming a ridge $3\frac{1}{2}$ miles long, with a height of from 20 to 50 feet. The country to the east of this chain consists chiefly of limestone gravel.

A small esker, known as Carrick Hill, occurs to the north of Edenderry. Still further north are two small chains, one near Thomastown, and the other near Ballinadrumny, the small town of Kinnegad lying between them.

IV. The System of Trim.—Near Trim, and to the east of it, a single chain of eskers commences, and runs from N.N.W. to S.S.E. for about six miles. Near its commencement its summit is 233 feet above sea-level, but the gravel mound, in which it ends, attains a height of 402 feet above sea-level.

Extending from the town of Athboy, up the valley of the Athboy river, a tributary to the Boyne, is a compound chain of eskers, which may be provisionally associated with the Trim system.

Several isolated chains occur in the Midlands, of which the relations cannot at present be determined; that at Clonaslee, and another at Geashill, may be cited as examples.

The chain of Mountmellick and Maryborough would appear to belong to the valley of the Barrow.

The Portumna Kame-Belt.—Though we have already crossed the ground of this belt (fig. 4.) in following the courses of the Killimor, Tynagh, and Duniry eskers, we have reserved the mention of it for this place, on account of its apparent individuality and exceptional character. This very remarkable feature of the Midland system is the occurrence of a great number of short esker and

gravel hillocks over a narrow tract of country, not more than one to two miles broad, which extends due north from Portumna for a distance of about 11 or 12 miles. The eskers, though short, are long enough to give evidence of a general northerly trend, and about Kiltormer, where several eskers of the more usual elongated form are associated with them, the northerly direction is maintained. Many of the eskers over this zone are distinguished by their curious forms, resembling the letters U, V, L, and Y. It will be convenient to distinguish this zone of thickly scattered mounds as the Portumna Kame-belt. Near the middle of its course a spur proceeds from it and extends eastwards towards Eyrecourt. Most of the eskers of this process trend north and south; but the end one, nearest to Eyrecourt, runs due east and west. The process may be termed the parallel series of Eyrecourt.

Having returned to this neighbourhood, we may take this opportunity of mentioning that sporadic occurrences of short eskers are common to the west of the Portumna belt; and about the head waters of the Ardultagh river they are richly strewn over a circular area of about three miles in diameter. It has already been shown that the Ballinasloe chain commences within this area; and it may now be added that another chain, the Dunsandle esker of Mr. G. H. Kinahan (about four miles north-west of Loughrea), arises here; this, however, takes a south-westerly course, following the waters of the small stream there. It passes the village of Dunsandle, and terminates near Riverville Castle. North of it another chain follows the valley of the Dooyertha river, near Rathgorgin. South-west of these are numerous scattered eskers, or broken esker chains, as those of Castleboy and Killrust, of Aggard and Monksfield, and a single ridge more to the west, which is remarkable for its association with Lough Fingall. Both lough and esker have approximately the same shape and dimensions, and run close together from north to south side by side. This is rendered the more interesting by the fact that both lake and esker rest on the bare rock of a driftless area.

The Caltra Chiasma.—Although this is within the area of fig. 2, where we have been already, we consider it here apart to emphasise its remarkable character. It is a singular arrangement of eskers to be seen north of Slievanulty, between the rivers Bunowen and Shiven, over the south-west corner of sheet 97 of the Geological Survey map. The eskers themselves are usually straight and simple; some are long in comparison with their breadth; others short, narrow ellipses; the most striking feature, however, is their arrangement in two groups of parallel members, the ridges of one group running from south-east to north-west, and of the other from south-west to north-east. The larger part of the north-eastwardly-directed group lies on the west of the district, and of the north-westwardly-directed group on the east thereof. The two groups, however, are not quite separate, but implicated with each other, so that some of the north-

eastwardly-directed ridges occur on the eastern margin of the north-westwardly-directed group, lying between some of the north-westwardly-directed ridges; and, similarly, some of the north-westwardly-directed ridges lie within the area occupied by the north-eastwardly-directed ones. For this reason it will be convenient to speak of the two groups as the Caltra chiasma, Caltra being a village lying within the system. Although most of the eskers of the chiasma are straight, there are a few exceptions; two, in particular, may be mentioned; they will be seen in the middle of the north-westwardly-directed group, and are of especial interest, since they only just fall short of uniting the different directions of the two groups in themselves. One commences as a north-westwardly-directed ridge, and curves round until it points east of north; its neighbour on the west overlaps it for the first half of its course, and continues to approach the north-east direction of the second group, without, however, quite succeeding in attaining actual parallelism. So that here the two groups may be said to inosculate.

This completes our survey of the two great systems of Irish eskers. Several isolated chains and ridges occur outside these systems, such as those of Roscrea, and those to the east of Lough Derg, to which we should add, on account of their interest as occurring in or near Dublin, that on which Christchurch stands, and the small chain of Greenhills and Lucan. Others, but they are not numerous, are to be found in parts of Ireland which lie outside the boundaries of our map.

Summary and Conclusions.

Our knowledge of eskers is, in many important respects, singularly incomplete; and there are many problems connected with their origin which might perhaps be readily solved by an appeal to the eskers themselves. Deeply conscious of my own ignorance respecting several particulars which yet may be accessible to observation, I had originally intended to publish the accompanying map without comment; but having been led to add descriptive matter, and then an account of the literature of the subject, I venture to complete this essay with a short summary of facts and general conclusions.

A map of an esker system (Pl. LXIX.) presents a remarkable resemblance to a map of a river system. The narrow linear outlines, the meandering course, the branches converging like tributaries, or diverging like the channels of a delta, the loops and knots are singularly alike in each.

The chief difference which distinguishes the esker chain from a river system is its discontinuity, gaps of various length, from a few yards to several miles, breaking it up into a number of links of unequal size.

The explanation of this feature has been much discussed; chiefly, it may be imagined, because it is susceptible of explanation in so many different ways on

the hypothesis of a melting ice-sheet. It might readily result from subsequent denudation. Surprise has sometimes been expressed that the eskers should have survived the turbulent movement of the streams discharged from the disappearing ice. Perhaps in these great gaps we have a measure of the breaching efficacy of the liberated floods. Equally possible, however, is the suggestion that the gaps are original, marking stretches of the glacial rivers where sediment was never deposited as might readily happen for reasons so many and obvious that it were waste of time to consider them.

The eskers of Ireland are usually confined to comparatively low ground; they are consequently mostly distributed over drift-covered country. The ground on which they stand seldom rises more than 350 feet above the sea-level, though some large isolated mounds are found at a height of 400 feet. Their height above the surrounding country is rarely over 70 feet, not often over 60 feet.

Their side slopes are subject to great variation, but are often steep, sometimes making an angle of 35° with the horizon; both sides may be almost equally inclined, but more commonly one side has a steep, and the other a gentle slope.

When both sides are fairly steep, it is probable that the esker was deposited in a narrow channel and was supported by the ice on both sides. When one side is gently sloping it is possible that the channel was wide, and that the esker rested against the ice only on one side.

The run of an esker system, as we may term the direction towards which its several chains and branches converge, may be with the slope of the ground, or against it. The system of Ballyhaunis is an example of the former case; the sub-system of Portumna of the latter. A system which runs with the slope of the ground in one part of its course may, however, run against it in another; as, for instance, the system of the Midlands, which runs with the ground on its western side, as in the case of the Portumna sub-system just cited, and against it on its eastern side, thus descending to the Shannon in the one case, and rising from it in the other. The explanation of this may fairly be postponed until we have taken into account the direction of the movement of the ice.

The structure of the Irish eskers, like that of those known in other parts of the world, differs greatly in different eskers, and even in different parts of the same esker. In some places, as pointed out in the earliest Memoirs of the Geological Survey, it is confused, consisting of a rubble of blocks of stone only slightly waterworn, but without glacial scratches, piled together in disorder; in other places it is beautifully stratified, coarse and fine gravel, sand, and occasionally clay, alternating in rapid succession. False bedding is common, and in many cases a rude tendency to so-called anticlinal structure is seen, *i.e.* the beds of stratified material conform more or less closely to the slopes of the esker. I should prefer

to call this over-cast bedding, since it appears to be due to the casting down of sediment over a steep slope; the material sometimes lies at a high angle.

At the base of some eskers horizontally bedded sands and gravels are often met with, and, in one instance, as pointed out to me by Mr. Praeger, in the Greenhills esker, near Dublin, this was seen to be beautifully ripple-marked.

What are evidently disturbances of the bedding, produced subsequently to its formation, are far from uncommon. In the Greenhills esker, close to Timon Castle, Dublin, a particular bed of pebbles can be traced along a horizontal course for a considerable distance; but at one place this is interrupted for an interval of about 20 feet; fragments of it, however, are clearly visible lying along an irregular curve beneath a mass of disorderly sand and gravel. Cavings in, such as this, suggest that blocks of ice become buried up within the esker, and by their subsequent melting the overlying material was deprived of support.

Faults are not uncommon, contortions are frequently, and reversed faults occasionally, met with. Mr. Close informs me that a good instance of a reversed fault was pointed out to him by Mr. F. J. Foot in a cutting through an esker on the right-hand side of the road going from Boyle, to Moygara, about four and a-half miles due west of Boyle, which is in county Roscommon. The settling of one side of the ice on one side of the esker might produce a thrust sufficiently powerful to produce a fault of this kind; it does not necessarily imply that the whole glacier was still in a state of flow.

The large blocks of stone resting on the surface of an esker, and sometimes included within it, to which the officers of the Geological Survey so frequently call attention, are readily explicable as morainic fragments left behind in the last stages of the retreat of the ice. In common with many other phenomena they suggest that the eskers on which they occur were deposited rather in tunnels than in open valleys of the ice.

Not at all infrequently a core of coarse and confusedly arranged material is found within a mantle of exquisitely stratified sand and gravel, which may be repeatedly faulted.

From all that I have seen of the structure of eskers, I should certainly conclude that in most cases they have been deposited on the place where they are now found by the action of running water, and that they have not been precipitated in mass from the bottom of sinking ice-canons.

A great number of observations on the direction of glacial striæ over many parts of Ireland have been recorded by the officers of the Geological Survey; but the most important systematic study of these and other indications of the movements of the glaciers of the Pleistocene Period, we owe to the Rev. Maxwell Close, whose Paper on the subject we have referred to above, p. 787. Mr. Close describes (i.) a system of rock scorings, which show the direction taken by the ice at the

time it was abrading the bare rocks of the country, and (ii.) a system of drumlins, which indicate its direction, after or during the deposition of the boulder clay. But these two systems, that of the striæ and that of the drumlins, correspond, giving concordant indications, and thus prove that the movement of the ice was that of a steady and persistent flow, throughout a great part of the Glacial Period.

Mr. Close has laid down these two systems on a map (given also in the *Geol. Mag.* for May, 1867), showing the general glaciation of Ireland, on which he also represents a third system of indications, those furnished by the transport of rocky material, and the evidence of this is in strict agreement with that of the two preceding systems. We have transferred to our maps of eskers some of Mr. Close's results, indicating a line of flow by a straight line, or, when its direction is known, by an arrow; the nature of the evidence is shown by a (Δ) for drumlin, a (Σ) for rock striæ, and a (T) for transport of material, placed by the side of the line or arrow.

It follows from Mr. Close's observations that, during the period with which his map is concerned, the area of Ireland was glaciated by ice formed upon its own surface, except the eastern side of Ulster, which was swept by an ice-flow from a little west of north to a little east of south, which flow doubtless came from the western side of Scotland. A great flow proceeded to move southward from the north-east neighbourhood of Carrick-on-Shannon; but evidently, in consequence of the resistance of the ice to the southward, it divided near where that town now stands, part going south-eastwards towards Dublin, and part turning sharply westward from the plain country and then north-westward, when it was joined by the northward flow from the head of Lough Corrib, to move off the present area of Ireland in the neighbourhood of Killala bay. The south-eastern part of Ireland has been glaciated by ice, first flowing eastwards, then south-eastwards, and then southwards; the county Clare and its neighbourhood was swept by ice moving south-westwards, the place of parting of these two great flows being about 18 miles inland of the head of Galway bay. The hill-country centres of ice-dispersion were all on the west of Ireland; there were none elsewhere; though there were many corry-glaciers on the east and south-east of Ireland.

The movement of the ice in the districts occupied by the esker systems is less completely known than in the regions surrounding them. Irish geologists are credited with a discovery they have not made, and are not likely to make, of a coincidence between the direction of eskers and ice-flow (Woodworth, *loc. cit.*, p. 205). Mr. Woodworth does not cite authorities; but the asserted coincidence, when it exists, is only accidental.

In this connection it may be pointed out that, in addition to striations, drumlins, and transport of material, we have a fourth criterion supplementing these, by

which the direction of ice-flow may be inferred. This is given by the bogs. It will be found that, in a district where the direction of the ice-movement has already been discovered from observations on drumlins and striæ, the smaller bogs present individually an elongated form running in the same direction as the ice-flow, or they form a network, the meshes of which are all mostly elongated in the same direction. The bogs were originally lakes in the boulder clay, and when these occur in the form of isolated elongated troughs, they may be regarded as the reverse of drumlins; when, on the other hand, they form a network of waterways, this may be owing to the existence of numerous drumlins rising above the level of the water. In either case, whether indicating an elongated trough or the presence of drumlins, the form of the bog becomes a valuable aid in the discovery of the direction of ice-movement by mere inspection of an ordinary geological map. On reference to Plate LXIX., it will be seen that in the case of the Ballyhaunis system all the evidence concurs in testifying to a movement of the ice from the south-east to the north-west, while the esker chains, for the greater part of their course, run manifestly at right angles to this, or from south-west to north-east. This would suggest that in their case the water channels in the ice were determined partly by crevasses. We have already seen that these eskers run against the slope of the ground, and it may be that the apparent convergence of the chain northwards, as described above, is to be interpreted as a divergence southwards, and that the water drained from the Ballyhaunis ice towards Lough Corrib and Galway Bay.

If now we turn to the Midland system we shall find that associated with a general absence of indications of the direction of ice-flow is a general absence of elongation in the form of the wide areas occupied by bog. From this it would appear that the movement of the ice in the centre of the country was sluggish; it probably accumulated here in an immense pool, and possibly persisted as a *piedmont* glacier up to the closing stages of the Glacial Period. In the case of the Portumna sub-system the flow of the ice, as shown by drumlins, bogs, striæ, and transport of material, was in the same direction as the run of the eskers, *i.e.* on the whole from west to east. That the subglacial streams flowed for a considerable distance in this direction is suggested by the occurrence already mentioned of Connemara marble and Galway granite in the esker of Parsonstown. The Portumna belt runs transversely to this east-and-west movement, and like the eskers of Ballyhaunis may have been determined by crevasses.

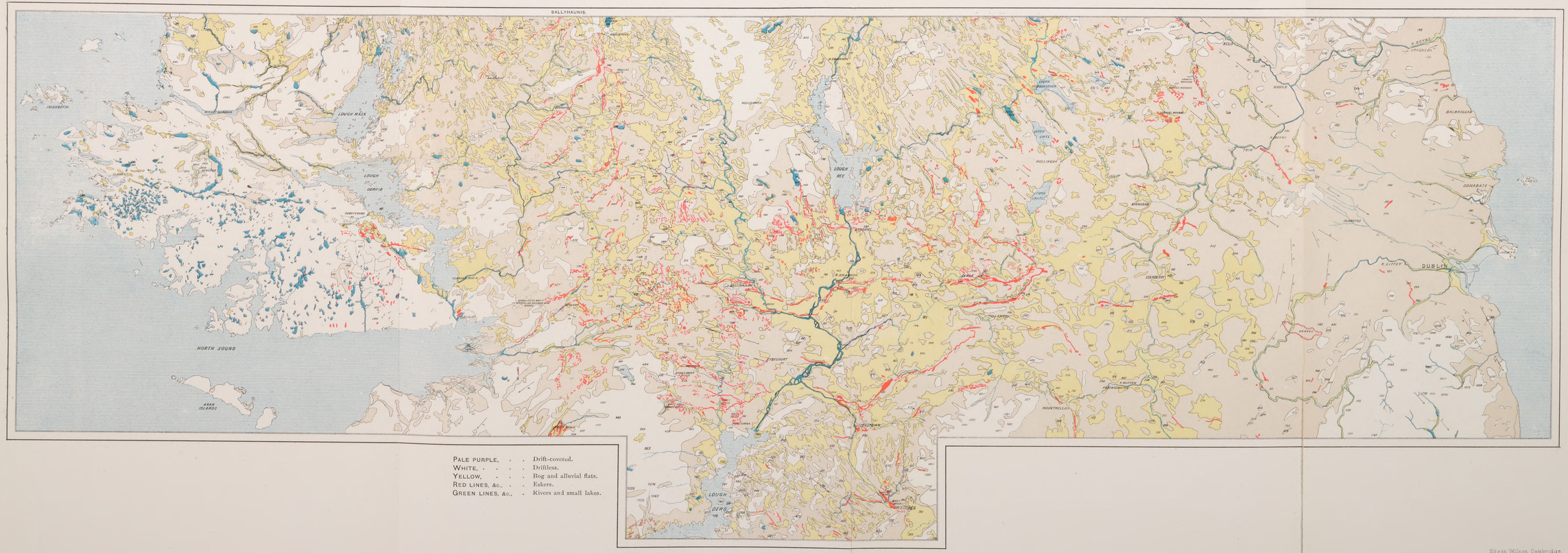
EXPLANATION OF THE MAPS.

The large map, Plate LXIX., is on a slightly smaller scale than one inch to eight miles, say one inch to 8·24 miles. The very pale brown indicates drift-covered ground, the white driftless ground, the yellow bogs and alluvial flats. The green lines and spots mark rivers and small lakes. The red lines and spots represent the eskers. The short, thin, straight lines, generally with arrow heads, show the direction of the ice-movement. (See also p. 820, *supra*.) The numbers scattered over the map give the elevation of the ground above the sea-level, in feet.

Figs. 2 and 4 exhibit portions of Plate LXIX. on a larger scale, viz. one inch to very nearly five miles. The white now means drift-covered ground, the horizontal ruling driftless ground, and the diagonal ruling bog, or alluvial flats. The thick lines (easily distinguishable from the lines indicating rivers) and the spots represent the eskers. The straight lines, generally with arrow heads, show, as before, the direction of the ice-movement.

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PALE PURPLE,	. .	Drift-covered.
WHITE,	. . . .	Driftless.
YELLOW,	. . . .	Bog and alluvial flats.
RED LINES, &c.,	. . .	Eskers.
GREEN LINES, &c.,	.	Rivers and small lakes.

MAP OF ESKERS.

Edwin Wilson Cambridge

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Bd.: 5,[2] = Pt. 11/13. 1895/96. - S. 539 - 822

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urn:nbn:de:bvb:12-bsb11788318-0